THE EXPERIMENTAL METHOD OF TESTING THE EFFICIENCY OF WARNING AND CRYPTIC COLORATION IN PROTECTING ANIMALS FROM THEIR ENEMIES.

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INTRODUCTION.

The selectionist theories regarding the significance and the causes of production of the so-called warning, mimicking, and cryptic coloration long preceded a knowledge of the food preferences of insectivorous animals sufficient to warrant such speculations. In fact, this knowledge is still almost entirely lacking for many parts of the world—including the Amazon valley, which is the home of the brightly colored Heliconiid butterflies and their mimics that suggested the mimicry theory to H. W. Bates. In 1861, Bates explained the numerous cases of mimicry of the butterflies of this family by butterflies and moths of at least five other families, by stating that the Heliconiidæ probably are unpalatable to insect enemies, and that the others disguised in their dress share this immunity.[1] He

[1] *Trans. Linn. Soc. Lond.*, XXIII, 1862, p. 510.

also proposed to explain cryptic resemblances, or the mimicry of inanimate objects by natural selection. Four years later, A. R. Wallace stated[2] that he agreed entirely with Bates as to the cause of mimicry, and cited many examples of the phenomenon from the Malayan region. In 1867 the same author first gave a definite theory[3] concerning the significance of the brilliant colors which are now commonly referred to as warning colors. In 1870[4] he extended the application of Bates' theory of cryptic and mimicking colors and advanced the results of experiments in support of the theory of warning colors.

It is not necessary at this time to trace the later development of the theory by Müller, Dixey, Poulton, and others. Suffice it to say that the original definite suggestion that conspicuous colors have been developed to advertise disagreeable qualities was the result of Wallace's cudgelling his brain at Darwin's instance, for an explanation of the coloration of certain insect larvæ, which obviously could not be accounted for by sexual selection. The theory has since been expanded to include conspicuous coloration in all groups of animals. A certain insect smells badly to man; is colored red and black, for example, it is conspicuous and nasty to us, hence it must be to insectivorous animals. Its striking color advertises its nauseous qualities and it is avoided after experience; in other words, is protected. So goes the original theory. Although it has been expanded to include all conspicuous forms, whether or not they are nauseous to man, its supporters seemingly find it impossible entirely to forsake the older anthropomorphic ground. Mimicry theories hold that a palatable form gains protection by resembling one of the conspicuous but nauseous ones, and that distasteful forms are mutually benefited by resemblance. Each of these theories, it may be repeated, was built up in the absence of evidence that the insects concerned were actually distasteful or palatable as claimed. This was the principal criticism made by the comparatively few who at the time dared question the all-sufficiency of natural selection, and it stands to-day the greatest obstacle to acceptance of the theories.

This criticism spurred the supporters of the theory to sporadic efforts to produce evidence in favor of their contentions. The favorite method of securing such evidence has been by experimenting with captive animals, and the principal body of alleged proof of the

[2] *Trans. Linn. Soc. Lond.*, XXV, 1866, pp. 19–22.
[3] *Proc. Ent. Soc. Lond.*, 1867, p. lxxxi.
[4] *Contributions to the Theory of Natural Selection*, 1870, Chap. III.

distastefulness of certain insects and the palatability of others consists of the results of experiments. The cry always is to test theories under experimental conditions, but there are many things which cannot be so tested. The very conditions of captivity and the limited choice of food constitute abnormalities which cannot fail to distort the food relations of most animals, and so modify the results of experiments that they bear little or no analogy to natural conditions.

In experiments play is allowed to the fancy of the experimenter, and the interpretation of facial and other expression of the subject has often been given more weight than the actual result of the experiment, that is, whether the insect was eaten or rejected. R. I. Pocock[5] very frankly admits this, saying, "It is quite clear that the plain record of an insect being eaten is no proof of its palatability. Better evidence on this head is supplied by the behavior of the bird towards it. After a little experience in the matter, I was able to satisfy myself, at all events, as to the approximate correctness of my interpretation of the bird's actions, and to judge thereby of the comparative palatability of the insects they tasted." This is honest confession at any rate, but the writer must take issue with this author as to the value of interpretation of behavior. "The plain record of an insect being eaten," which he holds up to scorn, may not show palatability, but shows something much more definite, namely, that the insect is acceptable food. Palatability in the sense used by some of the experimenters is entirely a figment of the imagination. This is proved by the many cases of refusal in captivity of insects which are eaten under natural conditions, and by the misinterpretation of the following among other features of the behavior of caged birds and other animals.

Wiping the bill or mouth: If a bird wipes its bill, or a lizard or frog its mouth, when it is being experimented with, the action is almost always credited as a sign of distaste. Yet nothing is more common than to see wild birds wiping their beaks across branches or other objects. It occurs at all times, apparently is often done in a purely mechanical way, and certainly has no essential connection with the taking of food or perception of tastes.

Dropping and picking up or in any way manipulating the prey is another thing usually taken as evidence of unpalatability, but nothing could be more at variance with conclusions drawn from

[5] *Proc. Zool. Soc. Lond.*, 1911, p. 810.

natural behavior. It is highly characteristic of many birds to thresh their prey about, and this is often continued until the object is broken in many pieces, which are separately swallowed. E. B. Poulton considered (*P. Z. S.*, 1887, p. 219) that a pupa would have been swallowed whole if palatable, but as it was crushed and the contents eaten it must have been unpalatable; and Weismann (*Studies in the Theory of Descent,* 1882, Vol. I, p. 341) thinks it readily conceivable that a certain caterpillar may not be unpalatable to lizards, because they swallow it whole, whilst it is perhaps distasteful to birds, because they must hack and tear it in order to swallow it. As a matter of fact, it is habitual for woodpeckers and jays to peck open pupæ and extract the contents, and smaller birds, as the chickadees and titmice, not only use this method when attacking pupæ, but for large larvæ also. Many birds hold the food between their feet and hammer it vigorously before eating, and others accomplish the same end by repeatedly picking it up and throwing it down. At least one experimenter, Jenner Weir, recognized such actions as natural, for he says, "All perfect Lepidoptera apparently require preparation before they are swallowed by birds; they are taken between the mandibles, shaken and bruised for a minute or two, and generally have the wings removed before they are eaten."[6] In many experiments, however, this same action is reckoned as a sign of disgust, if not as an actual rejection. Lizards habitually chew large prey before swallowing, snakes chew it or crush it by constriction; all of these actions are simply part of the normal preparation of food for deglutition, and in no sense of the word evidences of distaste.

Hesitancy and caution are usually translated as distaste. Does a bird of prey dislike the mouse it holds by a talon on its perch for hours at a time; does a butcherbird dislike the prey it impales on a thorn or wedges in a crotch for future reference? Does a cat play with a mouse because she hesitates to swallow so distasteful a creature? What animal does not employ dilatory tactics in feeding when it is not uncomfortably hungry? This subject naturally leads up to that of disregard, which may be looked upon as hesitancy prolonged.

Disregard may arise from many conditions, unrelated to the palatability of the food, such as varying appeal of the food to the captive animal according to its state of activity or health, or degree of hunger; or such as the size of the object offered, presence of the

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[6] *Trans. Ent. Soc. Lond.*, 1869, p. 22.

experimenter, or other disturbing elements. Disregard is a frequent phenomenon in experiments with birds of mixed feeding habits, which are most frequently used because more easily provided for in captivity. These birds have no great natural fondness for insects, and certainly not for adults of the order—Lepidoptera—most frequently used in the experiments. The insignificance of disregard is shown throughout Frank Finn's experiments, in the accounts of which (*Journ. Asiatic Soc. Bengal*, 1895, 1896, 1897), very common expressions concerning cases in which certain butterflies were not eaten in the presence of the experimenter are: "The butterflies were all gone later on," "Next day all the butterflies were gone," etc. In fact, more than 64 per cent. of the butterflies which were left in the cages were eaten in the absence of the experimenter, and more than 77 per cent. of those eaten belonged to the "nauseous" group. The experiments of S. D. Judd (see pp. 332–352) show that disregard bears no particular relation either to acceptances or to rejections, and certainly none to natural preferences. Thus, of the three categories of insects offered to the birds, namely, "warningly colored" insects, others "specially defended," and "non-protected" forms, practically the same proportions (17 to 19 per cent.) were rejected, while the percentage disregarded varied from 3 to 11.

In Poulton's tabulations of experiments (*P. Z. S.*, 1887) disregard is usually reckoned practically the same as a refusal. Indeed, the original tendency was to consider that disregard showed much greater distaste than any result following trial, for it is pointed out (pp. 193, 194) that the brilliant colors of caterpillars to be of value must generally prevent even trial, because of the fatal consequences to these larvæ of very slight wounds. However, Poulton states that out of thirty-seven cases in the "nauseous" group, fifteen were exposed to hungry animals, other food being withheld, and of the fifteen only three remained untasted. Of these two have been shown to be eaten under certain circumstances (p. 225). Poulton estimates disregard properly in one case, that of *Lasiocampa quercus* larvæ. These were disregarded by birds and lizards, and the comment on the evidence is, "Neutral as far as the adult larva is concerned" (p. 209). As a matter of fact, disregard is no more of neutral significance in this case than in the fifteen others in which disregard or disregard plus acceptance is the sole evidence upon which proof of distastefulness is claimed. The fact that nine of the eighteen insects of the "unpalatable" group are known to be eaten by wild

British birds further suggests the unreliability of disregard as a guide to natural tastes.

In consequence of the too great fondness of some experimenters for psychological deductions, the writer, in judging experiments, has separated "disregards" for the reasons above stated, and has taken cognizance only of rejections that resulted from actual trial. But a rejection has been credited for each time the experimenter says the object was refused, even if it was eaten later. This is certainly as great a concession in favor of the experiments as can be expected from one who believes not at all in their utility. Tabulations have been made anew (whenever possible) from the detailed accounts of the experiments. It cannot be hoped that these are free from error, but it may properly be assumed that they are approximately correct.

The earlier experiments especially are characterized by the average small number of tests of the various insects. For this reason, single or a very few acceptances or refusals have been held to prove the palatability or otherwise of a certain form. Thus in the eyes of those who had faith in experiments, results piled up in a really beautiful way. It is not out of order, however, to point out in advance that there are many inconsistencies between the various sets of experiments and that these show that conclusions based upon a few trials are extremely liable to be overturned.

An interesting case showing the danger of basing conclusions upon a single rejection is given by Jenner Weir (*Trans. Ent. Soc. London*, 1869, p. 22): "The imago of *Spilosoma menthastri* . . . . was tasted by the reed bunting, but not relished, and soon dropped; the . . . . bird, however, attracted by the fluttering insect, returned to it, and ultimately swallowed it." If the insect had been taken out, the single rejection would, of course, have stood as the reed bunting's record. A case illustrating the possibilities of single acceptances or rejections is R. I. Pocock's experiment on "the distastefulness of *Anosia plexippus*" (*Nature*, 87, 1911, pp. 484–485). A specimen was offered to eleven species of birds and refused a total of thirteen times by them, before it was offered to a tinamou, which swallowed it at once. Reversing the experiment thus might have given an exactly opposite impression of the palatability of this insect.

In the following pages the expressions accepted, rejected, and disregarded are often abbreviated to A, R, and D, respectively. In general, the experiments are reviewed in groups determined by the classes of animals tested.

Experiments with Invertebrates (Chiefly Insects).

Since Professor E. B. Poulton,[7] the most prominent supporter of the theories of warning and mimicking coloration, has come to the conclusion, from proper data—that is, records of insects collected with naturally captured prey—that predaceous insects in general are enemies of the "specially protected" groups, it is not necessary to review experiments relating to the food preferences of insects. It is worthy of note, however, that some of these experiments have often been quoted as affording support to the prevailing theories. Poulton's latest conclusion is proof, therefore, that even the ardent believers in the experimental method admit that an "ounce" of proof as to natural behavior is worth a "pound" of experimental evidence.

An annotated bibliography of experiments upon invertebrates is given for the benefit of those who may desire to consult the original accounts. Those entries marked with an asterisk denote experiments which were not undertaken with a view to testing protective adaptations.

Barlow, Edward. A short note on the Food-insects of the Mantis *Heirodula bipapilla* Serv. *Proc. Asiatic Soc. Bengal*, December, 1894 (1895), pp. 138–139.

Ate *Musca*, *Lucilia*, and its own species, and killed but did not eat the Hemiptera, *Cyclopetia* and *Physomerus*.

Belt, Thomas. *The Naturalist in Nicaragua.* London, 1888.

Experiments with Heliconii. "A large species of spider (*Nephila*) . . . . used to drop them out of its web when I put them into it. Another spider that frequented flowers seemed to be fond of them, and I have already mentioned a wasp that caught them to store its nest with" (p. 317).

Butler, A. G. Remarks upon certain Caterpillars, etc., which are unpalatable to their enemies. *Trans. Ent. Soc. Lond.*, 1869, pp. 27–29.

Spiders (*Ereiba diadema* and *Lycosa*) rejected larvæ of *Abraxas grossulariata* and *Halia wauaria* (p. 28).

Embody, G. C. [Food of fresh-water Amphipods in aquaria]. Sonderabdruck aus *Internat. Rev. d. ges. Hydrobiologie u. Hydrographie*, Biol. Suppl., III, 1911 (1912), pp. 4–6.

Freshly killed isopods, snails, earthworms, tadpoles, and bits of fish, and beef were eaten, but planaria were refused.

[Food of Hydra] p. 31.

Young *Hyalella* and *Eucrangonyx* were eaten.

Marshall, G. A. K., and Poulton, E. B. *Trans. Ent. Soc. Lond.*, 1902.

[7] See *Trans. Ent. Soc. Lond.*, 1906, pp. 363, 364, 401, 403, and 408.

Experiments on Mantidæ in Natal and Rhodesia (G. A. K. M.), pp. 297–313.

[Summary of these experiments] (E. B. P.), pp. 313–315.

Conclusions from experiments on Mantidæ (E. B. P.), pp. 315–319.

"We may safely conclude that outside the Acræinæ, and doubtfully the Danainæ, Mantidæ devour butterflies very freely, the species with warning colors as well as the others, and that they are far more indiscriminating than the majority of insect-eaters" (p. 316). "But Mr. Marshall's experiments yielded plenty of evidence of the positive refusal and acceptance, as it were, under protest of Acræinæ, so that there can be no doubt of their distastefulness to this class of enemy" (p. 317).

Despite this conclusion, the fact remains that these Mantidæ ate more Acræinæ than they rejected upon trial, and rejected no Danainæ. It should be noted, furthermore, that many of the rejections occurred in the last day or two of the life of the various individual mantids when no food whatever was taken.

Experiments on spiders in the Karkloof (G. A. K. M.), pp. 319–322. Results of experiments on spiders and the earlier experiments on Mantidæ: one probable meaning of tenacity of life in distasteful insects (G. A. K. M.) pp. 322–325, (E. B. P.) pp. 325–328.

"Experiments have convinced me that both spiders and mantises have no appreciation of warning colors" (p. 322). "It is quite probable . . . . that certain species of spiders, together with mantides and other predaceous insects, will be found among the chief, perhaps the chief, non-parasitic enemies of aposematic insects" (p. 327).

MARSHALL, G. F. L., and DE NICEVILLE, L. *The Butterflies of India, Burmah and Ceylon*, Calcutta, 1882–83.

"Mr. de Niceville has experimented with the carnivorous *Mantis* on many of the butterflies believed to be offensive to birds, and he has found *A. violæ* is the only butterfly which all the species of *Mantis* he has experimented with refuse to eat" (p. 318). This is all there is on the experiments.

MEISNER, OTTO. [Food of an Ant-lion and a Clerid in confinement.] *Ent. Bl.* Nürnberg, 5, Nr. 9, September 20, 1909, pp. 181 and 182.

A larva of the ant-lion (*Myrmeleon*) which had been fed only upon flies and caterpillars for a long time, afterwards rejected ants. A *Clerus formicarius* ate every *Adalia bipunctata* which got into its cage.

*PATCH, E. M. Predaceous Beetles and hibernating Insects. *Bul. 148, Maine Agr. Exp. Sta.*, November, 1907, pp. 273–276.

Pterostichus lucublandus was tested with numerous specimens of *Corimelæna pulicaria, Cosmopepla carnifex, Lygus pratensis,* and one *Serica vespertina*, all of which were eaten. Staphylinidæ were tested with the *Corimelæna, Lygus, Cosmopepla* and cutworms with same result.

PECKHAM, E. G. [Food of spiders and ants in captivity.] *Occas. Papers Nat. Hist. Soc. Wis.*, I, 1889, pp. 107, 109, 110.

Attidæ devoured flies, gnats, larvæ and other spiders, but would not touch ants. *Synageles picata* and *Synemosyna formica* are always hungry for gnats, but will not eat ants (p. 107). Ants devoured an ant-like spider, *Herpyllus*, which was placed in a vial with them (p. 109).

*Peckham, G. W. and E. G. The Sense of Sight in Spiders with some observations on the Color Sense. *Trans. Wis. Acad. Sci.*, X, 1894–5, pp. 231–261.

Remarks on food taken in captivity, but nothing in relation to protective adaptations of prey.

Plateau, Felix. Observations et experiences sur les moyens de protection de l'Abraxas grossulariata L. *Mem. de la. Soc. Zool. de France*, VII, 1894, pp. 375–392, 3 figs.

Experiences avec Araignees, pp. 385–388.

Spiders, *Amaurobius ferox*, and *Agalena labyrinthica* would not touch the larva of *Abraxas*. *Tegenaria domestica* attacked the larva, but could not pierce its tough skin. Both *Tegenaria* and *Epeira diadema* ate imagos, while *Agalena* rejected them.

Experiences avec Carabes et Dytiques, pp. 388–390.

Carabus auratus, *Dytiscus marginatus*, and *D. dimidiatus* freely devoured *Abraxas* larvæ.

*Pocock, R. I. Notes upon the habits of some living Scorpions. *Nature*, 48, 1893, pp. 104–107.

They ate cockroaches, blue-bottle flies, etc., in captivity.

Pocock, R. I. Further notes and observations on the instincts of some common English Spiders. *Nature*, 49, 1893, pp. 61–63.

It was found that the prey of *Agalena labyrinthica* consists largely of bees. A *Bombus* put in a web was enshrouded before it was killed; a blue-bottle fly was pounced upon at once, while a drone-fly (*Eristalis*) was cautiously attacked and killed, but not enshrouded.

*Porter, J. B. The habits, instincts, and mental powers of Spiders, genera, Argiope and Epeira. *Amer. Journ. of Psychology*, 17, 1906, pp. 306–357.

Experiments with food, but not in relation to protective adaptations, are described on pp. 334–338.

Experiments with Vertebrates.

FISHES.

In a paper entitled, "An Experimental Field-study of Warning Coloration in Coral-reef Fishes,"[8] Prof. Jacob Reighard records a variety of experiments to determine the significance of colors and flavors of prey to gray snappers (*Lutianus griseus*). The predaceous fishes were free and under normal conditions. The common prey

[8] Papers from the Tortugas Laboratory, *Carnegie Institution*, Vol. II, 1908, No. 9, pp. 257–325.

of this species at the time of the tests was found to be the sardine (*Atherina laticeps*), a silvery fish that could readily be stained any color. A large number of *Atherina* stained vermilion, yellow, green, blue, or purple were eaten practically as rapidly as fed. Others dyed and treated with formic acid, formaldehyde, red pepper, quinine, ammonia, or carbon bisulphid were taken with equal readiness. *Atherina* were made unpalatable, however, by sewing in their mouths bits of the tentacles of medusæ, and an association of this unpalatability with a color (red) was established in the individuals of a colony of 150 snappers. The association was found to persist at least five weeks.

The brightly colored fishes of the coral reefs were then offered to the snappers, and they attempted to capture all offered, and actually did take all but one species, of which the single large specimen offered escaped. The species taken were of a variety of colors, including colors and patterns considered as typically warning. In several species "conspicuousness is combined with unpleasant attributes in the form of defensive spines, the typical warning combination, yet these fish were all instantly taken" (p. 303).

It was further found "that the gray snapper discriminates with great rapidity and delicacy between the various possible food elements of its environment, which are not conspicuously different from each other," thus proving that the bright colors of the reef fishes would be unnecessary even were their possessors unpalatable.

Hence "the conclusion is reached that the conspicuousness of coral-reef fishes, since it is not a secondary sexual character and has no necessary meaning for protection, aggression, or as warning, is without biological significance" (p. 320).

AMPHIBIA.

In Countries Other than the United States.

Experiments dealing chiefly with Amphibia are few. Those of Poulton with *Hyla*[9] are cited in another place. A. G. Butler, Eltringham, Plateau, and Finn also record short experiments with animals of this class. Butler published[10] the fact that he had found the larvæ of *Abraxas grossulariata*, *Halia wauaria*, and a sawfly, all fed upon gooseberry, to be distasteful to frogs (and lizards). He asks: "May it not be possible that the plant transmits some pecu-

[9] *Proc. Zool. Soc. Lond.*, 1887, pp. 269–274.
[10] *Ent. Monthly Mag.* 5, 1868, pp. 131–132.

liar acid to the larvæ which feed upon it, such as to cause their rejection as food by small reptiles, etc.?"

Plateau found that *Rana temporaria* and *Triton punctatus* rejected, while *Triton alpestris* disregarded the larvæ of *Abraxas*.[11] Eltringham cites a very few tests made with a salamander. The animal accepted earthworms and honey bees, and disregarded larvæ of *Pieris brassicæ*.[12] Finn found that the Indian bull-frog (*Rana tigrina*)[13] took all butterflies offered to it, except two *Danais chrysippus*, of which species it ate one.

In the United States.

A number of experiments upon Amphibia have been performed in the United States. These are discussed in two groups, those on toads and those on frogs.

Toads.—In company with Dr. A. K. Fisher, the writer once attempted to give a toad (*Bufo lentiginosus*) his fill of hymenopterous food. This occurred on Plummer's Island, Md., about 1905. Honey bees and wasps of the genera *Polistes, Sceliphron,* and *Vespa* were captured, their wings were clipped, and they were put down so that they would crawl in front of the toad, which was partially domesticated about the cabin and was not much disturbed by the movements of humans. The toad took every insect offered, although at times he showed considerable but ludicrous signs of discomfort. Not less than 30, and perhaps as many as 40 Hymenoptera were taken by this animal in about an hour. He finally left the spot, apparently to get away from a locality characterized by such extremely spicy food, which nevertheless he was apparently unable to refuse.

In another experiment performed by the writer at the same locality, on August 6, 1911, another toad was also fed *Polistes, Pelopæus,* and another stinging wasp, none of which was refused. A sphinx moth, a small white moth, several ants and flies also were taken. The toad attempted to eat a katydid (*Cyrtophyllus perspicillatus*), but found it too large. A small *Heterocampa* larva, colored green and red, was eaten, and then a *Julus* was put before him. As soon as it began to crawl he seized it by one end and, not getting a good hold, ejected it. It then crawled over his head. This might be construed by some as evidence of dislike, but I think that if the *Julus* had been fairly seized it would have gone down. At any rate the case well

[11] *Mém. de la Soc. Zool. de France*, VII, 1894, pp. 383, 384.
[12] *Trans. Ent. Soc. Lond.*, 1909, pp. 473, 474.
[13] *Journ. Asiatic Soc. Bengal*, 66, 1897 (1898), p. 533.

illustrates the danger of drawing conclusions from scanty experimenting, for stomach examinations show *Julus* to be a favorite food with toads. A. H. Kirkland says in his valuable paper on the economic value of the toad:[14] "Myriapods form a constant article of diet for the toad. Species of the genus *Julus* were present in the majority of the stomachs examined, the largest number found in a single stomach being seventy-seven. These creatures form 10 per cent. of the food for the season."

Mr. Kirkland's examinations of stomachs serve to check another set of experiments which is claimed to show that squash bugs (*Anasa tristis*) are seldom eaten by toads. The account of these experiments by C. M. Weed and Albert F. Conradi is as follows:

"The common toad has been generally considered an enemy of the squash bug, being frequently referred to in this connection in articles concerning the pest. We made a large number of observations on this phase of the subject, the most interesting result being the discovery that the odor given off by the bugs will actually kill toads if confined in a small open vessel, such as a wide-mouthed bottle. Some of these experiments as recorded in a published letter by Mr. Conradi are as follows:[15] When a squash-bug nymph of the fifth stage was suddenly introduced into a half-pint, open, wide-mouthed bottle containing a half-grown, live toad, so that the batrachian would get the full effects of the pungent fumes secreted by the bug, the toad was thrown into a temporary stupor, the effect being similar to that of chloroform. As the number of bugs was increased, the effect on the toad was increased. When as many as seven bugs were introduced, the toad fell into a profound stupor, from the effects of which it died in the course of twenty-four hours.

"On September 8, an adult toad that had been kept in the laboratory vivarium with a scant food supply for several days, was placed in a quart jar of the same construction as the one mentioned above, and eight bugs were introduced; these bugs, however, had been so much disturbed previously that the source of the pungent secretion had been temporarily exhausted. The toad hesitatingly devoured three, after which she would remove with her front feet every specimen that made an attempt to ascend the wall of her enclosure; but these bugs were not eaten. The toad was then transferred to another jar of the same size and construction, and eight bugs were suddenly

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[14] *Bul. 46, Hatch Exp. Sta.*, 1897, p. 15.

[15] *Science*, N. S., Vol. XIV, No. 360, November 22, 1901, pp. 816, 817. See also *Science*, N. S., Vol, XIX, No. 479, March 4, 1904, pp. 393, 394.

introduced from the squash leaf so that the animal would get the first and fullest effects of the odor; the result was that the toad went through a series of contortions followed by a short period of stupor similar to that mentioned before. Upon recovery the toad was again removed to the vivarium, where it now lives in partial hibernation.

"A young, red-spotted salamander was affected and killed as easily as the half-grown toad, while for the common field frog a greater number of bugs were required to bring about similar effects, the frogs also being killed. Many experiments with snakes were tried, but no ill effects from the secretion of the bugs were apparent.

"The odor that the bug secretes is contained in a clear, slightly greenish liquid expelled from the extremity of the alimentary canal; when it comes in contact with the air the odor is given off almost instantaneously while the liquid remains to evaporate.

"Further observations showed that toads in confinement would eat squash bugs when very hungry, but we do not think that toads ordinarily devour many of the pests."[16]

It is most obvious that the conditions of these experiments are never even faintly simulated under natural conditions. The conclusions in the last paragraph, being based on the results of the experiments, are therefore unwarranted. Moreover, they do not agree with the statements of other observers relating to the habits of the toad under normal conditions. Kirkland found *Anasa tristis* in collected stomachs,[17] as did also Judd and the writer.

Kirkland briefly records an experiment of his own as follows:

"The writer once confined for study a large toad in a shaded out-of-door box filled with damp earth. To provide suitable and sufficient food for it was quite a task until an entirely satisfactory expedient suggested itself. A hard bread-crust was soaked in molasses and placed in the cage. Bees, wasps, ants, flies, and beetles came to this bait, and it was most interesting to watch the toad seize the flying insects, often before they had alighted on the bread. Stinging insects, bees, wasps, etc., when swallowed by the toad apparently produced uncomfortable sensations for a short time. Fish-worms when captured by the toad often prove too much to be swallowed at once, and when this is the case the fore limbs are brought

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[16] "The Squash Bug," *Bull. 89, New Hampshire Agric. Exp. Sta.*, February, 1902, pp. 21–23.

[17] *Bul. 46, Hatch Exp. Sta.*, 1897, p. 26.

into use to force the unfortunate worm into the capacious gullet of its captor."[18]

In this connection we may quote C. F. Hodge,[19] who, in giving instructions as to the use of toads as insect catchers in houses, says: "Sugar solutions should not be used [as bait] on account of the danger to honey bees which a toad will take in great numbers despite their stings." Hodge quotes[20] a feeding test by Miss E. M. Foskett, the insect used being *Macrodactylus subspinosus*. Miss Foskett says: "One day I gathered a quantity of rose bugs in a tin box, sat down in the shade beside my queer pet and began feeding bugs to him. At first I did not count, but finding his appetite so good, I started to count. When I had counted over eighty bugs and the toad showed no signs of wishing to conclude his meal, I picked him up. . . . . Previous to my beginning to count, he had taken anywhere from ten to twenty bugs. He was quite a large toad, but the bugs were large, too, and very 'scratchy.'"

The American Sportsman (Vol. 3, No. 2, October 11, 1873, p. 23) reports a series of experiments with toads by Dr. Thomas Hill. This account does not have a thoroughgoing appearance of verity, but this may be not a reflection on the experiments themselves, but upon the reporting. It is said a toad ate "yellow-striped" locusts, earthworms, and at one meal twenty-three squash bugs and ninety-four larvæ of *Pygæra menistra* [*Datana ministra*].

C. V. Riley briefly states[21] the results of offering larvæ of *Anosia plexippus* to various animals, as follows: "Prompted by . . . . experiments made in England, I was led to make similar ones with our gayly colored Archippus larva, and the result fully accords with that obtained by Mr. Weir, for neither turkeys, chickens, toads, nor snakes would touch it."

Included with some notes on the Florida chameleon (*Anolis principalis*), Dr. S. Lockwood records[22] an observation upon captive toads. Two of these animals ate, respectively, three and two potato beetles (*Leptinotarsa decemlineata*), after which they would take no more. Dr. Lockwood then remarks: "It was specially observable of the one which had swallowed the three spearmen, despite the grotesque gravity of his demeanor, that there was a certain dolorous

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[18] *L.c.*, p. 11.
[19] *Nature Study Leaflet, Biol. Ser. I*, Worcester, Mass., 1898, p. 11.
[20] *L. c.*, p. 10.
[21] *Third Ann. Rep. on the Insects of Missouri*, 1871, p. 148.
[22] *Am. Nat.*, 10, 1876, p. 8.

air about him, as of one suffering from an overdose of Doryphora. Though kept some two weeks with no other food, neither Bufo would touch a spearman again."

No better illustration could be asked of the misleading character of experimental results nor, it may be added, of the highly imaginative conclusions drawn therefrom. Notwithstanding the "dolorous air" of these toads by reason of potato-beetle diet, the fact remains that toads habitually feed on potato beetles. Tenney,[23] Riley,[24] Kirkland,[25] Garman,[26] and Chittenden[27] among others record toads as enemies of potato beetles. The writer has found the remains of no fewer than twelve *Leptinotarsa decemlineata* in a single casting of a toad.

Frogs.—In an article entitled, "Habit Formation in Frogs,"[28] A. A. Schaeffer says: "Individuals of three different species of frogs, *Rana clamata*, *R. sylvatica*, and *R. virescens* learned to avoid disagreeable objects, such as hairy caterpillars, in from four to seven trials or possibly less. Such habits persisted for at least ten days, but this point was not thoroughly tested.

A *Rana clamata* formed a habit of avoiding earthworms treated with chemicals in two trials. This habit persisted perfectly for only a short time, covering five trials in about twenty-two hours. The habit persisted somewhat imperfectly for five days. After an electric stimulus had been applied, earthworms were not eaten for seven days, although mealworms were eaten" (p. 334).

These observations point to the conclusion that any color may be regarded as warning, provided a sufficiently disagreeable impression becomes associated with it.

Another experimenter, Charles W. Hargitt, was led to doubt the quick formation of such associations by *Hyla*, as is shown by his comments on the behavior of a tree frog toward Hymenoptera. In food taking, he says: "Hyla behaves quite similarly to others of its kind. It seems not to notice any except moving objects. A spider may remain quietly in a given part of the cage for hours or days undisturbed. If it assume an active attitude it is almost certain to be taken very promptly. It is thus with any prey. The insects most commonly supplied were flies, small beetles, grass-

[23] *Amer. Nat.*, 5, 1871, pp. 170, 171.
[24] *Fourth Mo. Rep.*, 1872, p. 16, and in many other publications.
[25] *Bul. 46, Hatch Agr. Exp. Sta.*, 1897, p. 25.
[26] *Bul. 91, Ky. Agr. Exp. Sta.*, 1901, p. 66.
[27] *Circ. 87, U. S. Bur. Ent.*, 1907, p. 12.
[28] *Journ. An. Behavior.*, Vol. 1, No. 5, Sept.–Oct., 1911, pp. 309–335.

hoppers, spiders, etc. On one occasion a small wasp was released in the cage and at once began to buzz about or run up the sides of the cage actively. It was but a few moments ere a specimen leaped eagerly and captured the prey. Then a most interesting performance took place. No sooner was the wasp seized than it was whipped into the mouth, and in turn stung the frog; the frog in turn showed a very lively appreciation of that fact, and made an apparent effort to eject the creature; but the process of ingestion had gone too far and deglutition was completed without further ado, nor did the frog show the least further sign of distress. On another day the operation was repeated and very much after the fashion of the preceding. It may be doubted whether Amphibia show any particular discrimination based on that type of experience."[29]

Salamanders.—Albert M. Reese, in a paper on the "Food and Chemical Reactions of the Spotted Newt, *Diemyctylus viridescens*," says that the animals show no difference in reaction toward bits of raw meat and earthworms nor to the juices from these substances.[30]

A specimen of hellbender (*Cryptobranchus allegheniensis*) which ejected remains of a crawfish soon after capture, refused to eat any of these animals placed in its aquarium later.[31]

Reptiles.

Experiments in Asia.

Among Frank Finn's many experimental contributions to the theory of natural selection are two which deal with the food taken by lizards. The first[32] deals with the Indian lizard (*Calotes versicolor*), both captive and free individuals of which were offered a variety of adult Lepidoptera. The results of feedings of the free and confined individuals agree very well except in the case of butterflies of the genus *Euplœa*. The record for these insects with lizards in a cage is A 4 R 1, and with those unconfined, A 1 R 4. Species of *Danais*, *Delias eucharis*, and *Papilio aristolochiœ* were freely eaten, and Finn concludes: "The behavior of these reptiles certainly does not appear to afford support to the belief that the butterflies, at any rate, usually considered nauseous, are distasteful to them" (p. 48).

The second series of experiments we refer to are reported in

[29] "Behavior and Color Changes of Tree Frogs," *Journal of Animal Behavior*, Vol. 2, No. 1, Jan.–Feb., 1912, pp. 53, 54.
[30] *Journ. Animal Behavior*, Vol. 2, No. 3, May–June, 1912, p. 207.
[31] "Oconomowoc," *Forest and Stream*, 8, No. 20, June 21, 1877, p. 320.
[32] *Journ. Asiatic Soc. Bengal*, 65, 1896 (1897), pp. 42–48.

Natural Science, December, 1892.[33] They deal chiefly with the East African lizards, *Mabuia striata* and *Hemidactylus mabuia*. Several presumably distasteful insects were refused by these species. They refused wood lice also, which were eaten, however, by *Gerrhosaurus major*.

Experiments to determine the tastes of *Calotes* were also performed by R. C. Punnett in Ceylon.[34] Punnett concludes that the lizard tested (in confinement) by him showed no discrimination in the choice of various adult Lepidoptera offered. "The presumably distasteful *Danais* was eaten before the presumably palatable *Euschema* or *Mycalesis*, and the so-called distasteful *Euplœa* was taken before the supposedly palatable *Junonia iphita* of not very dissimilar coloration. Nor was any hesitation manifested towards *Papilio aristolochiæ* with its postulated evil taste and marked warning coloration" (p. 13). Punnett also found the larvæ of the last-named insect as well as an adult *Danais plexippus* were eaten by another lizard (*Lyriocephalus*). "From such experiments as these one can hardly fail to draw the conclusion that *Calotes* as well as *Lyriocephalus* will readily eat anything in the way of butterflies that they come across. Nor is this surprising, in view of the fact that such noxious creatures as the large ant (*Œcophylla smaragdina*) and hairy caterpillars constitute a considerable proportion of the contents of their stomachs. They certainly do not appear to exercise that nice discrimination with regard to butterflies, which is necessary for the establishment of mimicking forms on the theory of natural selection" (p. 13).

Lieut.-Col. Neville Manders also performed experiments with lizards[35] in Ceylon, using the following species: *Calotes versicolor, C. ophiomachus, C. nigrilabris, C. zeylanica*, and *Ceratophora stoddarti*. The last two species are smaller than the others and would not try to eat butterflies either when caged or free. The experiments with free specimens of the other three species resulted as follows: Lepidoptera classed as edible, A 11; Lepidoptera classed as nauseous, A 17 R 3. Manders says one of the latter was at first refused because of large size, then partly eaten, and the other two were too dry.

He further states "that so long as the butterflies remained perfectly still, they were entirely unnoticed by the lizards, though they might be in close proximity to them" (p. 708). This indicates that

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[33] *I, No. 10*, pp. 746, 747.
[34] *Spolia zeylanica*, VII, Pt. XXV, September, 1910, pp. 12, 13.
[35] *Proc. Zool. Soc. Lond.*, 1911, pp. 707–710.

color is not the stimulus to capture, but that motion is. Manders concludes: "It would seem that those who assume that reptiles take no part in the production of Batesian or Müllerian mimicry are correct, though further experiments are required" (p. 710).

Experiments in Europe.

A series of experiments by H. Eltringham with *Lacerta viridis*[36] have as their main point the demonstration that a certain lepidopterous larva (*Boarmia rhomboidaria*), was more distasteful to the captive lizards when it had fed on ivy than when fed on apple. In addition, a number of other insects and other invertebrates were used in the experiments. No general conclusions are given. Possible comparisons with Poulton's tables of experiments (1887) are as follows:

	Poulton's tables, 1887.	Eltringham.	Animal tested.
Pieris brassicæ, larva	R.	A 4 D.	*Lacerta viridis*.
Apis mellifera	A many.	R.	" "

Later, Eltringham says that the caterpillars referred to in his previous experiments are not *Boarmia rhomboidaria*, but *Odontoptera bidentata*. The adult moths were eaten by lizards, to which they were fed by Messrs. Eltringham and Pocock. The latter found that they were acceptable also to a bird, *Graculifera melanoptera*. Eltringham concludes that the distastefulness of the larvæ was not intrinsic, but due to the character of the food in their digestive tracts.[37]

Plateau states[38] that seven *Cistudo europæa* ignored the caterpillar of *Abraxas grossulariata*, while one tried and rejected it. *Coluber æsculapii* and *Lacerta muralis* disregarded the larvæ and rejected them when placed in their mouths.

Experiments in America.

Few experimental tests of the efficiency of the protective adaptations of insects have been made in the United States. The most important series hitherto published in full was performed by Annie H. Pritchett and was reported in the *Biological Bulletin* (Vol. 5, pp. 271–287, 1903). The animals used were *Sceloporus floridanus*, *Gerrhonotus infernalis*, *Crotaphytus collaris*, *Cnemidophorus sexli-*

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[36] *Trans. Ent. Soc. Lond.*, 1909, pp. 471–478.
[37] "Edibility of Lepidopterous Larvæ," *Proc. Ent. Soc. Lond.*, 1910, pp. xxxi, xxxii.
[38] *Mém. de la Soc. Zool. de France*, VII, 1894, p. 383.

neatus, *Eumeces* sp., and *Phrynosoma cornutum*. A large variety of invertebrates were offered the lizards, with the following principal results: (*a*) Only one instance of a lizard eating a dead insect; (*b*) insects that move slowly do not attract the attention of the lizard so much as do the more active forms, hence those that remain quiescent are rarely even attacked; (*c*) insects below a certain size are apparently not perceived by the large species of lizards; (*d*) large beetles having hard elytra are seldom eaten; (*e*) the myriapod *Julus* was not eaten by any lizard; (*f*) although the combinations of black and yellow, black and orange, or black and red are supposed to serve the purpose of warning coloration, all insects possessing these colors were, at one time or another, eaten, with the possible exceptions of *Panorpa nuptialis* Gerst. and a malodorous Lygæid bug.

Some experiments with *Sceloporus undulatus* by Dr. S. D. Judd which have never been published may now be put on record for purposes of comparison with the series just noted. The results of these tests follow:

ORTHOPTERA:	
BLATTIDÆ—*Stylopyga orientalis* (black)	A 2
MANTIDÆ—*Stagomantis carolina* (dark brown)	R
LOCUSTIDÆ—*Microcentrum* sp. (green)	R
GRYLLIDÆ—*Gryllus* sp. (dark brown)	A 3
COLEOPTERA:	
CARABIDÆ—*Carabidæ* (undet.)	A
Harpalus pennsylvanicus (black)	A
Scarites subterraneus (black)	R
COCCINELLIDÆ—*Coccinella* sp. (warning colors)	R 2
Hippodamia sp. (warning colors)	R
Adalia sp. (warning colors)	D
Epilachna borealis (yellow and black)	A
DERMESTIDÆ—*Dermestes* sp. (nearly black above, white below)	A
LAMPYRIDÆ—*Chauliognathus* sp. (warning colors)	R
SCARABÆIDÆ—*Ligyrus* sp. (reddish-brown)	R 2
Lachnosterna sp. (reddish-brown)	R 2
CHRYSOMELIDÆ—*Leptinotarsa decemlineata* (yellow and black)	R 2
Diabrotica sp	A
HETEROPTERA (all strong smelling):	
PENTATOMIDÆ—*Brochymena* sp	R
Nezara hilaris (green)	R
REDUVIIDÆ—*Arilus cristatus* (red-brown, wings with bronzed tips)	R

LEPIDOPTERA:	
ARCTIIDÆ—*Hyphantria cunea* l. (yellow, brown, and black, very hairy)	A 2 R 2
LIPARIDÆ—*Orgyia leucostigma* l. (red, black, white, and yellow, hairy, tufted)	R 2
DIPTERA:	
MUSCIDÆ—*Calliphora erythrocephala* (metallic blue)	D

Sceloporus floridanus and *S. undulatus* are very close relatives; hence so far as the lizards are concerned, comparsions between the two sets of experiments are not far-fetched. Unfortunately, the insects offered have nothing more than the genus in common, and that in only a few cases. However, the comparisons possible on this basis are given:

	Pritchett.	Judd.
Brochymena	D	R
Chauliognathus	A 24 R 2	R
Harpalus	A 3 D 4	A
Gryllus	A 5+	A 3

Summing up Judd's experiments, we have the following results:

	A.	R.	D.
"Protected" group[39]	4	10	1
"Non-protected" group	8	10	1

Evidently these *Sceloporus* were hard to please, accepting barely more than a third of all the insects offered; 66 per cent. of the individuals of "protected" species were refused and 52 per cent. of the "non-protected" group.

Dr. S. Lockwood briefly records[40] the food habits of the Florida chameleon (*Anolis principalis*) in captivity. The lizards ate flies and spiders, but would not take the potato beetle (*Leptinotarsa decemlineata*), and, in fact, were not fond of beetles at all. Dr. Lockwood cites an observation by Bell, that a pet *Anolis*, catching an *Epeira diadema* by the leg, was bitten by its captive and death soon ensued.

MAMMALS.

Finn records[41] brief experiments with an East African mongoose (*Crossarchus fasciatus*). This animal refused one specimen of a frog (*Xenopus lævis*) and ate and vomited another. It ate and

[39] That is those "warningly" colored or otherwise "specially defended."
[40] *Am. Nat.*, 10, 1876, pp. 7, 8.
[41] *Natural Science*, I, No. 10, December, 1892, pp. 746–747.

vomited parts of a lizard (*Mabuia striata*), but the lizard was nevertheless entirely eaten. The mongoose was unwilling to eat birds and refused to attack a conspicuous milliped (*Spirobolus*). An obscurely colored milliped also was refused by a lemur (*Galago*).

Another of Finn's experiments concerning the tastes of mammals for insects deals with a tree-shrew (*Tupaia ferruginea*).[42] The conclusion is: "It is obvious that this animal had a very strong objection to the 'protected' Danainæ and *Papilio aristolochiæ*, as it so constantly refused them" (p. 532). This is a fair summary of the experiment except as it applies to *Papilio aristolochiæ*, the record for which was A 2 R 2.

Marshall and Poulton have published[43] accounts of experiments with a mongoose (*Herpestes galera*), baboons, and a monkey (*Cercopithecus pygerythrus*). The mongoose tested by Marshall (pp. 376–378) refused but one insect consistently and had only two trials with that. The animal was tested with birds as food and refused five out of ten kinds offered. Two of the five refused have colors of the type called warning and this is peg enough upon which to hang some speculations as to distastefulness. Nothing is said about the equally conspicuous colors of two of the species eaten, viz., *Nettopus auritus*, blackish-green, white and rufous; and *Saxicola pileata*, chestnut, black, and white. The results of single trials of several insects with *Cercopithecus pygerythrus* are recorded on p. 379, and pp. 380–392 are devoted to an account and discussion of more extended experiments with baboons. Poulton tabulates the Coleoptera accepted and rejected by the baboons, and from these tabulations it appears that about 75 per cent. of the beetles rejected had warning color patterns, as did about 55 per cent. of those accepted. It is unfortunate that there are no records of the natural food of these African mammals that can be used as a check on the experimental results.

MIXED GROUPS OF ANIMALS.

Brief notes on experiments with a marmoset and lizards are included in E. B. Poulton's description of the "means of defence adopted by the larva of *Stauropus fagi*" and the "defensive value of 'tussocks' of *Orgyia* and the associated black intersegmental markings."[44]

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[42] *Journ. Asiatic Soc. Bengal*, 66, 1897 (1898), pp. 528–532.
[43] *Trans. Ent. Soc. Lond.*, 1902, pp. 376–392.
[44] *Trans. Ent. Soc. Lond.*, 1888, pp. 581–588 and 589–591.

We are told that when at rest the larva of *Stauropus fagi* resembles a withered beech leaf. Next, it is stated that the second and third pairs of thoracic legs are so held that they resemble, "in the most beautiful manner, a bunch of brown scales (the stipules of the foliage leaves) which enclose the buds of the beech, and hang down after the latter are unfolded." As if withered beech leaves, thus adorned, were common during the life of this larva and as if beech were the only food plant of the larvæ. As a matter of fact, *Stauropus* feeds on the foliage of several other woody plants. When aroused the larva is said by Poulton to assume a terrifying attitude, the main suggestion of which is a spider-like creature.

It is rather amusing to contemplate the variety of resemblances claimed for *Stauropus* larvæ. For instance, Poulton himself, ten years later, insists upon an entirely different resemblance from those above mentioned. He then says:

"The young larvæ of *Stauropus fagi* have often been described as resembling ants. The likeness has recently been analyzed in much detail by Portschinski (*Coloration marquante et Taches ocellées*, V, St. Petersburg, 1897, p. 44). This acute observer considers that the head of the larva represents the globular abdomen of the ant, while the head and antennæ of the latter are suggested by the larval caudal shield with its two appendages. He believes the disturbed larva represents an ant which has seized and is endeavoring to carry off some object on the branch which it is exploring. . . . . During the present summer (of 1898) I have had the opportunity of studying these larvæ. The young larvæ were thought to be ants by all the friends to whom they were shown. One lady considered that they were 'double ants'—an interpretation evidently due to their disproportionate length and to the head-like appearance of the caudal shield."[45]

Birchall[46] states that the young larva closely resembles a twig of beech with unopened buds, and that when feeding its likeness to a great earwig or to a *Staphylinus* is very striking. He also remarks upon the general suggestion of a crustacean in the larva's aspect, but he further desires "to speak doubtfully of the sharp eyes of a bird or *Ichneumon* being deceived when engaged in its own special business, by any such colorable imitation" (p. 233).

Mrs. Bazett[47] notes the great resemblance that the newly hatched

[45] *Journ. Linn. Soc. Lond., Zoology*, Vol. XXVI, 1898, pp. 589, 590.
[46] *Ent. Monthly Mag.*, XIII, 1877, p. 231.
[47] *Ent. Rec.*, II, 1891, p. 210.

larva bears to an ant, while Kirby[48] says it is from the extraordinary appearance of the larva that the species derives its name of lobster moth.

Thus the larva of *Stauropus* is supposed to mimic more or less closely, objects in both the vegetable and the animal kingdoms, and within the limits of the latter, representatives of five orders (not to mention ants carrying prey nor double ants), belonging to no fewer than three classes of the phylum Arthropoda. It is evident that the predaceous foes of *Stauropus*, had they only the imaginative powers of its human observers, could have a banquet of many diverse courses, each of which would be merely *Stauropus* in disguise.

Poulton says: "I should not, however, have ventured to speak so plainly of the meaning of the various details in the defensive attitude of the larva if I had not been able to rely upon the best support attainable—the support yielded by direct experiment."[49] He would have been approximately correct if he had said the poorest support attainable, but let us see what the support is. A marmoset and a lizard were offered one *Stauropus* larva each; they showed caution in attack, but *each ate the larva.* Rather a slender basis, one would say, for four pages of argument on the special defence of the creature.

The continuation of the argument—defence against insect enemies —is even more far-fetched. When irritated the larva displays black patches on certain segments, and Poulton thinks "it is clear that the black marks exposed by the larva are calculated to suggest to the approaching enemy [parasite] that the individual [larva] in question is already occupied." Super-parasitism is too common an occurrence to warrant the belief that parasitic insects are warned away by any visible signs of preoccupation.

The tussock moths (*Orgyia antiqua* and *O. pudibunda*) are supposed to be protected by the fine hairs of the tussocks which come out easily in immense numbers. Poulton says: "This interpretation is *entirely* due to experiment. A larva of *O. antiqua* was introduced into a lizard's cage and, when attacked, instantly assumed the defensive attitude. An unwary lizard seized the apparently feasible part of the larva: most of the tussock came out in its mouth, and the lizard seemed greatly troubled by the fine hairs and did not touch the larva again" (p. 590). An *Orgyia pudibunda* larva was killed but not eaten by another lizard.

[48] *The Butterflies and Moths of Europe,* 1903, p. 46.
[49] *Trans. Ent. Soc. Lond.,* 1888, p. 585.

The results of most of the earlier experiments with various animals are brought together by Prof. E. B. Poulton in a paper entitled, "The Experimental Proof of the Protective Value of Color and Markings in Insects with Reference to their Vertebrate Enemies" (*Proc. Zool. Soc. Lond.*, 1887, pp. 191–274). It is convenient to review these experiments collectively. Those covered by Poulton are as follows:

Butler, A. G. Remarks upon certain Caterpillars, etc., which are Unpalatable to their Enemies. *Trans. Ent. Soc. Lond.*, 1869, pp. 27–29.

Animals experimented with were *Lacerta viridis*, frogs, and spiders. In part previously published in *Ent. Monthly Mag.*, 5, 1868, pp. 131, 132.

Poulton, E. B. Diary of observations during 1886. *P. Z. S. Lond.*, 1887, pp. 269–274.

Using *Lacerta muralis*, *L. viridis*, and *Hyla arborea*. The earlier sketch of some of the results of these experiments is: "Some experiments upon the protection of insects from their enemies by means of an unpleasant taste or smell." *Rep. British A. A. S.*, 1886 (1887), pp. 694, 695.

Weir, J. Jenner. On Insects and Insectivorous Birds, and especially on the relation between the Color and the Edibility of Lepidoptera and their Larvæ. *Trans. Ent. Soc. Lond.*, 1869, pp. 21–26.

The birds used were seven species of finches, one weaver bird, one muscicapid, one pipit, and one thrush. Few of them are highly insectivorous species.

Weir, J. J. Further Observations on the relation between Color and the Edibility of Lepidoptera and their Larvæ. *Trans. Ent. Soc. Lond.*, 1870, pp. 337–339.

Birds used as in his previous experiments.

Weir, J. J. Diary of observations during 1886. *Proc. Zool. Soc. Lond.*, 1887, pp. 268, 269.

Experiments with lizards: *Lacerta viridis*, *L. agilis*, and *Zootoca vivipara*.

Weismann, A. *Studies in the Theory of Descent.* London, 1882, Vol. I, pp. 328–341.

Principally experiments with *Lacerta viridis*.

The main burden of the first half of Poulton's paper is the searching of the results of these experiments for support of "Wallace's original suggestion 'that brilliant or conspicuous larvæ would be found to be refused by their enemies'" (p. 196). In the preliminary sketch[50]

[50] *Rep. British A. A. S.*, 1886 (1887), p. 694.

of his own experiments Poulton says: "Wallace had predicted that brilliantly colored and conspicuous insects would be refused by the ordinary vertebrate enemies of their class." This statement, which was a "bull" from the very beginning (inasmuch as we cannot reckon as enemies of an insect those animals that refuse to eat it) is wrongly stated by Poulton in both of the above cases. Wallace's original suggestion, as reported in *Proc. Ent. Soc. London*, 1867, p. lxxxi, is that, "as a rule, the brilliantly colored larvæ were those which were distasteful to *birds*." Poulton further twists this in his table headings to a suggestion "that brilliant and conspicuous larvæ would be refused by some at least of their enemies," a much later modification of Wallace's statement.

However, this later claim would be admitted without argument did we accept Poulton's usage of the term enemies as including practically all insectivorous animals. Even if there were no other factors involved, the relative sizes of the larvæ and of various insectivorous animals in themselves establish limits to the number of predators upon a certain form; thus numerous large larvæ will be free from attacks of all but a small proportion of insectivorous foes. Very small larvæ, on the other hand, will be overlooked by many predators. That is, considerations entirely aside from coloration will limit the number of enemies of any given form. It is evident that all vertebrates cannot be enemies of the same insect; enemies and prey form indefinite groups that intermesh in a multitude of combinations. Consequently, an insect cannot be said to be protected, because certain vertebrates more or less ignore it, when they perhaps have no opportunity and certainly in many cases no necessity for feeding on it in the wild state.

Poulton first tabulates the results of experiments with eighteen species of "undoubtedly conspicuous larvæ," and concludes: "The first and obvious result of the first table is, with only one entirely antagonistic exception, the most complete demonstration of the truth of Wallace's suggestion that a highly conspicuous appearance would be found to be accompanied by some unpleasant attribute" (p. 205). Upon close inspection of this table, we find there are two, not one, species that are not shown to be distasteful to any animal, namely, *Deilephila euphorbiæ* and *Lasiocampa pini;* eight not refused by anything are included because they were disregarded by birds. The writer has explained above why disregard cannot be accepted as a test at all. The inadvisability of so doing is shown by the fact that at least three of these eight species of larvæ, namely, *Orgyia*

antiqua, Cucullia verbasci,[51] and *Hybernia defoliaria,* are known to be eaten by British wild birds. The other eight species included in the table comprise three others disregarded by caged birds, two of which are also eaten by British wild birds. These eight, however, were used chiefly in experiments with lizards, and four of them were accepted as well as refused upon trial. Of the four only refused, one (*Porthesia auriflua*) was eaten by hungry lizards in Poulton's experiments of 1887.[52] Another, *Pieris brassicæ,* was eaten more often than refused in Pocock's experiments (reviewed later), and a third which was rejected by frogs and lizards is known to be eaten by nestlings of *Parus major.*

Exception may be taken to remarks about some of the species listed in this table. For instance, *Deilephila euphorbiæ* was eaten by a captive lizard, and Newman says, "sea-gulls and terns devour them in numbers." We may add to the list of enemies the maüse-bussard, on the authority of Schuster.[53] Poulton's comment on this larvæ is: "The correlation of a startling appearance with some unpleasant attribute must probably have existed once if not now. Have we a case in which hunger or opportunity have caused the enemies to neglect the latter and therefore to benefit by the former?" (p. 199). We cannot so conclude, unless we admit also that similar warning coloration (*D. euphorbiæ* is "black, red, and yellow or white") would lose its meaning (admitting for the purposes of argument that it has a meaning) to the same enemies in all other cases.

It is of interest to note that *Hybernia defoliaria,* included in this table because disregarded by captive birds, was found in the stomachs of three species of British birds by Robert Newstead.[54] Schuster (*l. c.*) records many species of birds as enemies of this larva as well as of *H. brumata.*

Table II includes four larvæ which only become conspicuous when approached and detected; one is not shown to be unpalatable to anything, one was both eaten and refused by lizards, and another was eaten by at least two species of birds and avoided without trial by two or more other species. The fourth species was refused by lizards and poultry, but eaten by nestling great tits.

One of the larvæ listed in this table has been made the basis of some

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[51] See particularly the note, "Do birds eat the larvæ of Cucullia?" by H. D'Orville, *Entomologists' Monthly Mag.,* VI, June, 1869, p. 16.

[52] *Rep. British A. A. S.,* 1887 (1888), p. 764.

[53] *Ent. Bl.* Nürnberg, 5, Nr. 7, July 15, 1909.

[54] *Suppl. Jour. Bd. Agr. Lond.,* XV, No. 9, December, 1908.

of the most far-fetched theorizing imaginable. *Chœrocampa elpenor* is its name; "When approached the anterior part of the body is distended and resembles a serpent-like head (of the cobra type)" (p. 206). In Weismann's experiments, "A tame jay ate the larva at once; sparrows and chaffinches (wild) were frightened by it, and would not come near a seed trough in which it was placed; fowls were evidently frightened, but in the end cautiously attacked it, when it was soon eaten." Lady Verney notes that small birds "would not come near a tray with crumbs on it on which the larva had been placed" (p. 206). The larva of *Chœrocampa* is a large one (the ocellated spots are present only in last stage; if so useful, why is this the case?) and its size alone is sufficient to explain the actions of the small birds. In the case of the sparrows at least, almost any strange object of the same size might cause the same reaction. Anything new about their regular haunts is viewed with suspicion.

In regard to the Cobra-like appearance of *Chœrocampa*, Poulton says: "It is likely that the terrifying appearance of our own larvæ probably first arose in the tropics, where the imitated cause of alarm to the enemies of the larvæ is real and obvious. And it is probable that the success of the same method in countries where the reptilian fauna cannot be said to constitute a source of alarm is due to the inherited memories of a tropical life which live on, as that instinctive fear of anything snake-like which is so commonly exhibited by the higher land vertebrates, including ourselves" (p. 204).

What a characteristic piece of selectionist reasoning(?); at least four very debatable biological propositions, namely, the tropical origin of the European fauna, its origin in a part of the tropics having cobras, and instinctive fear in man and other vertebrates, are practically taken as established facts. Aside from these assumptions, the argument is very amusing also when contrasted with that insisted upon by selectionists, in a hundred places, that birds have no instinctive knowledge of what is suitable for food, but must learn by experience. If an instinct of cobra fear is present in birds whose remote ancestors may possibly have seen cobras, it would seem that instinct about such an every-day matter as food were not a point to strain at. However, it is obvious that both arguments cannot well be supported by any but the exceedingly versatile.

Table III includes seven "not inconspicuous larvæ which are not nocturnal and which do not conceal themselves." Two are not shown to be unpalatable to anything and four are included on the basis of disregard by birds or lizards, at least two of which are eaten

by wild birds. While the remaining one was refused by three species of birds and disregarded by others, it also is eaten by wild birds.

Table IV presents the results for "bright-colored or conspicuous insects other than larvæ." It deals with fifteen forms, four of which are not shown to be distasteful to any animal; two are included on the basis of disregard only, and four were accepted and refused by the same class of enemies. One of the remaining five, *i.e.*, *Anthrocera filipendula*, imago, refused by lizards in these experiments, was eaten by lizards in the 1887 experiments (*l.c.*). Concerning another insect of this group, namely, *Abraxas grossulariata*, Poulton notes (p. 220) his opinion that Butler's record of frogs eating the moth must be a mistake. It is noteworthy, however, that he uses others of Butler's records without question. Butler later affirmed the correctness of his note, and showed that the same insect is taken by some birds.

Tables I–IV deal with forty-four insects, nine, or 17 per cent., of which are not shown to be distasteful to any animal; another nine were both accepted and rejected by the same class of enemies. Eighteen were either disregarded or rejected by birds, and at least nine of these are known to be eaten by wild British birds. We have pointed out above inconsistencies of some of the other cases with other experiments. In fact, as may be seen on p. 313, in seven out of eight possible direct comparisons of these experiments with those of Pocock, the only other extensive series using British insects, the results are inconsistent.

Eight of the insects of the distasteful groups in these tabulations were fed to hungry lizards, in experiments performed by Poulton in 1887,[55] and all were accepted. The behavior of the lizards in the cases reported contrasts strongly with that shown in the previous experiments as shown in the following table of comparisons.

	1886.	1887.
BIRDS:		
Orgyia antiqua, larva	D	A
Vanessa urticæ, pupa	R	A
LIZARDS:		
Euchelia jacobæ, l.	A 2 R 4 D	A
Pygæra bucephala, l.	A 3 R 3 D	A
Porthesia auriflua, l.	R 2	A
Anthrocera filipendula, ad.	R	A
Abraxas grossulariata, l.	A 1 R 7 D 2	A

[55] "Further Experiments upon the Protective Value of Color and Markings in Insects," *Rep. British A. A. S.*, 1887 (1888), pp. 763–765. These experiments, dealing with frogs, lizards, and a marmoset, and including a few of A. G. Butler's notes on birds, are not reported in full. Hence they are not reviewed.

FROGS:

Crœsus septentrionalis, l	A	A

Thus it appears that these experiments are inconsistent among themselves, and from the fact that at least fifteen of the forty-four insects alleged to have been proved distasteful by the experiments are known to be eaten by wild British birds, we are justified in suspecting that the experimental results do not accurately indicate behavior under natural conditions.

A fifth table by Poulton comprises the results of experiments with insects which are protectively colored or which evade their enemies by other means. On the theory, therefore, all of these insects should be eaten freely by insectivorous animals. However, in sixteen out of sixty-eight cases, more than 23 per cent.,[56] the "evidences of distaste" are fully as strong as in the majority of the cases in the first four tables. Taking this fact in connection with that previously adduced, to the effect that 17 per cent. of the "protected" insects were not shown to be "unpalatable" to anything, and the additional fact that sixteen out of the forty-four, or 36 per cent., were included on the basis of disregard (some of them being eaten also), it is quite clear, that the insects, etc., were sorted out into the various tables, in accordance with the requirements of the theory, experimental evidence to the contrary notwithstanding. If authors are not consistent in the interpretation of the results of experiments, how can they expect others to have faith in them?

Poulton tries to explain the refusals of certain "protectively colored" imago Lepidoptera; for instance, with regard to *Vanessa urticæ* he says (p. 246): "I have no doubt that the refusal of some frogs was due to scales only," and of *Pieris brassicæ*, "eaten readily by all lizards, but not much relished, I believe, because of the mechanical difficulty of the scales and wings and not from being actually unpalatable." We cannot accept these explanations (which no doubt are true) without asking that they be made to cover the refusals of *all* adult Lepidoptera (of proper size for the animal experimented with). This would affect four species of Table IV and seven in Table V. We find Poulton later regarding *P. brassicæ* as intrinsically unpalatable (*P. Z. S.*, 1911, pp. 864, 865).

The inconspicuous larvæ of *Mania typica* were tasted and rejected by *Lacerta muralis*, Poulton's comment is: "At first sight a most

[56] This does not take into account earthworms and fly larvæ, which were rejected as well as refused, although the fact is not stated in the table.

startling difficulty, yet it is evident from the behavior of the lizards that they fully expected the larva to be palatable, in itself a strong confirmation of the suggestion that nearly all such larvæ are palatable" (p. 243). This is another argument that cannot be accepted unless it is also applied to the rejections of *conspicuous* larvæ upon trial, and this latter evidence rather than disregard is all the experiments yield that is worth any consideration. In fact, if impartially applied, this argument would do away with the experimental evidence of the efficacy of warning colors in all cases in which the insects were tasted before refusal. In other words, it would be just as fair to presume that these conspicuous larvæ also were expected to be palatable, "in itself a strong confirmation of the suggestion that nearly all such larvæ are palatable."

The experiments performed by R. I. Pocock, Superintendent of the London Zoological Gardens, like those just reviewed, cover a variety of vertebrate orders. A far larger number of species both of predators and prey were used than in any other experiments yet recorded. The captive animals included twenty-six species of mammals, ninety-six of birds, and seven of lizards, of which only six birds and one lizard occur naturally in England. The insects used were, of course, chiefly native. Even if we believe that experimental results have any value as indicating natural behavior, we can only conclude that the conditions of these experiments invalidate the findings, for of what possible value can it be to know the likes and dislikes of exotic animals for British insects?

The account of these experiments is in *P. Z. S. Lond.*, 1911, pp. 809–864. Mr. Pocock thinks his experimental results have "an important bearing upon the criticism sometimes advanced against the theory of warning coloration and mimicry as applied to butterflies, namely, that birds under natural conditions are seldom seen to eat these insects. Hence it has been inferred that birds cannot be reckoned as serious enemies of butterflies. Whatever may be the explanation of the circumstance," Pocock says, "I am tolerably sure, from the behavior of the two classes of animals when pitted against one another that the inference drawn therefrom is erroneous. The insectivorous birds in our aviaries seemed to know at once what the butterflies were; they were on the alert the moment one was liberated and pursued it with determination and precision, following its every turn and twist, and either catching it upon the wing or pouncing upon it after settling. It is true that this predatory deftness may have been acquired in relation to the chase of insects

other than Lepidoptera; but unless the birds recognized butterflies in general—a group which cannot be mistaken for other insects—as part of their natural prey, it is difficult to understand their eager excitement at the sight of those I offered them" (p. 811).[57]

Before quoting further, let us look into this argument a little: it is characteristic of the selectionist style. He is very charitable in admitting that predatory deftness *may* have been acquired in chasing other insects than butterflies. A little reflection will convince anyone, be he ignorant or not concerning the important constitutents of bird food, that butterflies even if eaten, can furnish but a small percentage of bird food, namely, an amount proportional to their numbers among diurnal insects as a whole. Hence a correspondingly small amount of training in predatory deftness can possibly have been acquired from capturing them. Pocock finds it difficult to understand the eager excitement of the birds at the sight of Lepidoptera, unless they recognized them as such; this after telling us on the preceding page of "the exceeding keenness of the birds for the insects brought to them. This was no doubt due in a measure to our inability in the Gardens to feed the birds on living insects other than mealworms."

Caged canaries, sometimes become frantically excited when a grasshopper or other insect is held up to the bars of their cage—they may never have seen an insect in their life before, they only know there is something they want. Pocock's parenthetical expression concerning Lepidoptera—"a group which cannot be mistaken for other insects"—directly opposes many arguments by selectionists relative to the resemblances of Sesiidæ to Hymenoptera; but any argument to establish the present point without reference to its bearing on other phases of the theory is a long-standing rule among selectionists. Continuing his argument, Pocock says: "Again, unless the species of butterflies used for the experiments are, or were in the past, habitually preyed upon by birds,[57] whence comes the extraordinary skill the liberated specimens . . . . displayed in dodging the swoop of birds in midair? Having repeatedly seen the aim of the pursuing bird baffled by the evasive twist of the butterfly, I cannot doubt that the insect's behavior was prompted by the instinct to escape an habitual enemy of its species, of the same class, and with the same predatory methods" (p. 811).

[57] It is worth pointing out that the disciple is here arguing directly against one of the cardinal teachings of the master, as Poulton iterates and reiterates, "acceptance is not proof of palatability" (*Trans. Ent. Soc. Lond.*, 1902, pp. 436, 317, 348, and 389).

Suppose a different experiment were performed: let some muskrats (*Fiber*) be put into an aquarium with some sea-lions; would their efforts to escape indicate previous experience in evading enemies of the same class? Not at all, it would indicate merely adaptation to expert progression in the same medium. The relations of birds (in general) to bats and of birds (again in general) to dragonflies are instances illustrating the same fact, but which are due to no general predatory relation between the groups. The wonderful powers of flight of many of the Syrphidæ are strictly comparable to that of butterflies, as the adults feed only at flowers and have no need of expert flight for predatory purposes; also they do not need it so highly developed for defense, for rather a small proportion of birds are capable of catching insects so expert on the wing. The extreme rapidity and dexterity of flight of humming-birds has no possible relation to their prey, nor need it have been developed to its present perfection to evade species that might be inclined to prey upon hummers. When Mr. Pocock arrives at the true reason for the extraordinary powers of flight of humming-birds, he will undoubtedly be less insistent upon the predator-evasion theory as an explanation of the tortuous flight of butterflies.[58]

Pocock further says: "Those who hold on the negative evidence above stated, that birds are not to be reckoned as serious enemies of butterflies, must be called upon to supply some explanation other than that above proposed of the marked reactions between these two classes of animals when brought into contact with one another, and to show reason why what takes place in the aviary may not be regarded as indicative of similar occurrences in nature" (p. 812).

The pertinent retort to this statement is that it is the selectionists who first claimed and who still claim that birds are important enemies of butterflies, and it is up to them to produce real evidence in favor of their contention. So far they have brought forward little except results of experiments. Pocock's own results, namely, the consumption of large numbers of British insects by exotic animals, should have convinced him that what takes place in the aviary may not necessarily be regarded as indicative of similar occurrences in nature. The point may be further illustrated by the following. Suppose a

[58] It is a matter of common observation that butterflies constantly exercise their powers of flight by playing with other butterflies even of different species. They often dart at falling leaves, flying bits of paper, and even birds. The writer saw (March 27, 1912, Plummer's Id., Md.) a *Vanessa antiopa* dash at and come within a few inches of a phœbe (*Sayornis*), that had just perched after one of its customary quick sallies at insect prey. The bird, a highly insectivorous species, paid no attention to the butterfly.

man has fired his last shot ineffectually at a charging tiger or rhinoceros; he naturally shows a "marked reaction" by taking to his heels, not because he or his ancestors have had similar experiences, but because he can run. So with the butterflies, skilful efforts to escape do not necessarily indicate previous racial experience of the same nature.

The principal failing of the selectionists always has been a vast ignorance of what wild birds really eat. They have made very little effort to acquire such knowledge, and their speculations throughout show the lack of it. Practically the only large body of authentic information on the natural food habits of birds is contained in the records of the United States Biological Survey. They comprise detailed identifications of the contents of more than 48,000 bird stomachs representing all families of birds and collected in hundreds of localities in the United States at all seasons. The United States has a goodly representation of butterflies, yet only five of these 48,000 stomachs contained remains of Rhopalocera. It is hoped this will be more satisfactory to the selectionists than the "negative evidence" they are accustomed to cite with contempt.

The extreme artificiality of Pocock's experiments and the inapplicability of the results to the natural relations of British birds and insects are so evident that it is not worth while to comment on the details. A few comparisons of the results with those of experiments recorded by Poulton are of interest as showing the inconsistency, *inter se*, of experiments. It has not been possible to collect a large number of such comparisons because Poulton's experiments were chiefly with lizards and few with birds, while the opposite is true of Pocock's. The varying stages in which the insects were presented also tend to limit comparisons. The table includes all possible direct comparisons and only one pair in eight shows real correlation.

	Poulton.	Pocock.
BIRDS:		
Vanessa urticæ, larva	D	A 7 R 4 D 1
" " pupa	R	A 2 R 2 D 1
Clisiocampa neustria, larva	D	A 1
Euchelia jacobæ, ad.	A	A 1 R 4
Cosmotricha potatoria, larva	D	A 1 R 4 D 1
Anthrocera filipendula, ad.	A	R 4
LIZARDS:		
Apis mellifera, worker	A	R 3
Pieris rapæ, ad.	A 20	A 2

Notes on Pocock's experiments, by Prof. E. B. Poulton, are given

on pp. 864–868, and show his customary facility in drawing conclusions satisfactory to himself from the most refractory evidence. For instance, he says: "The experiments on the *Pierinæ* support the conclusion that the perfection of the under surface procryptic resemblance affords a true criterion of the degree of palatability. *Pieris brassicæ,* with its conspicuous gregarious larva and imago larger and less cryptically colored than the other three species . . . . was distinctly the least palatable" (pp. 864, 865). The records of acceptances and rejections of the three species of *Pieris* are as follows: *Pieris rapæ,* A 10 R 2, a proportion of 5 to 1; *Pieris brassicæ,* A 40 R 33, $1\frac{1}{6}$ to 1; and *Pieris napi,* A 8 R 8, 1 to 1; *P. napi* thus being the least favored in the experiments. These figures are reproduced not because the point as to relative palatability is of any importance, especially as an indication of natural preferences, but merely to show that the experimental results are not accurately judged by those most interested in them. It is of interest to compare Pocock's results with *Pieris brassicæ* with those obtained by Dr. G. Rörig in Germany. Pocock records the pupæ of this insect as A 1 R 8 D 3, and the adult as A 16 R 7 D 1, while Dr. Rörig says:[59] The pupæ of the Kohlweisling "were eagerly torn open by all the titmice," and the adults "were always freely eaten by all the birds which I have tested."

Poulton bases considerable speculation upon the unpalatability of *Araschnia levana,* the record for which in the experiments is A 20 R 10. He follows this with a page of theorizing on the probable mimicry of *Melitæa* by *Hesperia,* and says that the experimental "results as a whole leave little doubt that *Melitæa* is distasteful to many birds, and that it does actually possess the qualtities which would render it an advantageous model for the Hesperiidæ" (p. 867). As a matter of fact, the experiments with birds and *Melitæa* described on pp. 826 and 827 show that it was finally refused by only one bird; it was eaten by thirteen species, seven species of which took nine specimens without hesitation. Two birds which dropped the first specimen offered them later took one and two, respectively, including those dropped. The final record for birds is A 18 R 1. If this is considered proof that *Melitæa* is advantageous as a model, the demands of the theory are most modest.

On p. 867 he also refers to *Melanargia* as a highly distasteful genus; its record in the experiments is A 14 R 4. Another extract from

[59] *Arb. Biol. Abt. f. Land. Forstwirts. K. Gesundheitsamte,* 4, 1903, p. 47.

Poulton's remarks is, "Although so many insectivorous animals in confinement disregarded the special defence of *Formica rufa*, there can be little doubt that such defence is very effective in the wild state. It is impossible on any other hypothesis to account for the conditions under which the species exists, swarming in vast numbers in restricted areas and an easy prey to any enemy that would dare to attack" (p. 868). Here we have a case where experimental results are not in accord with the theory, and it is evident that it is so much the worse for the experiments. Where the evidence is of a supporting nature, experiments are extolled to the skies. Pocock, who tries to stick consistently to the experimental results which for *Formica rufa* were an indefinite number of acceptances and no rejections by a monkey, A 13 R 0 by birds, and two refusals by lizards, says: "The unavoidable conclusion that these insects are palatable is rather surprising in view of the frequency with which ants are mimicked in the tropics" (p. 849). In deeming it impossible for the ants to live as at present unless specially defended, Poulton takes the struggle for existence too seriously. In fact, he seems to think all gregarious insects must be specially protected, thus overlooking periodical cicadas, migratory locusts, canker-worms, army-worms, etc., which usually occur in large numbers and are eagerly attacked by a great variety of insectivorous foes.

Poulton further remarks: "It was also apparent in many of the experiments that the unpalatability of conspicuous Lepidoptera was . . . . far more obvious to the birds than the mammals. In view of the part which birds are believed to play in the production of mimetic resemblances, it is obvious that this inference may be highly significant" (p. 868). The writer has tabulated the acceptances and rejections for mammals and birds, including only those Lepidoptera which were refused by some species, and the result is mammals A 19 R 10, or about 34 per cent. refused, and birds A 112 R 80, or about 41 per cent. refused. Hardly enough difference to warrant the comment quoted.

A very interesting series of experiments with frogs, lizards, birds, and mammals upon a good variety of insects and other invertebrates as subjects were performed by Beddard and Finn at the London Zoological Gardens and recorded by the former in his volume entitled *Animal Coloration* (1892, pp. 149–166). Mr. Beddard's principal conclusions are as follows: "It is quite clear from these experiments that insects which exhibit warning colors are by no means always exempt from attack. The opinions of insect-eating

mammals, birds, and reptiles appear to vary as to the edibility of this or that insect. . . . . But these experiments do show that very generally, though not always, a disagreeable taste is associated with a conspicuous and varied coloration. On the other hand, precisely the same deductions can be drawn by watching the behavior of animals when offered inconspicuously colored insects" (p. 155).

As in previous cases, we will give the direct comparisons that can be made between these and other sets of experiments. Four out of seven contrasted pairs are contradictory.

	Poulton's Tables, 1887.	Beddard.	Animals tested.
Armadillo vulgaris	A	A 2	*Lacerta viridis.*
Lithobius forficatus	A	R	" "
Pieris brassicæ, l.	R	A 5 R 2 D 1	Lizards.
Abraxas grossulariata, l.	A 1 R 7 D 2	R 1 D 2	"
Vespa vulgaris	D	A 2	"
Euchelia jacobæ, l.	A 2 R 4	A 1 R 3 D 1	"
	Pocock, 1911.	Beddard.	
Pieris brassicæ, l.	A 20 R 18	A 2 D 1	Birds.

Beddard justly remarks (p. 166): "None of these experiments are thoroughly satisfactory; it is so difficult to interpret them, and they are often contradictory, for a bird will eat one day what it has refused before. The experiments that have been made are like most other statistics—they may be made to prove anything. A careful series of observations upon the contents of the stomachs of wild birds would be the nearest approach to a satisfactory solution of the difficulty; but there are obvious objections to this mode of investigation."

Fortunately, this objectionable method has been pursued to some extent in England, *i.e.*, by Newstead, and to a slight degree the work serves as a check on experiments with British birds and insects. Beddard gave an earwig to a green woodpecker, which made a great deal of fuss over it, but ended by swallowing it; Newstead found these insects in two stomachs of green woodpeckers, one of which contained 23.[60]

Merely for the sake of completeness the very brief notes upon experiments by Thomas Belt[61] may be given here:

A tame white-faced monkey always killed but did not eat Heliconii (pp. 316, 317).

[60] *Suppl. Journ. Bd. Agr.* [*Lond.*], XV, 1908, p. 64.
[61] *The Naturalist in Nicaragua*, 1888.

Lampyridæ were "invariably rejected by the monkey, and my fowls would not touch them") p. 317).

A red and blue frog was not touched by fowls and ducks, but one of the latter tricked into taking one rejected it (p. 321).

We may add also those of Haase:[62]

Erithacus rubecula had to be starved into eating *Zygæna trifolii* (p. 20).

Fowls always rejected *Danais chrysippus*, but eagerly ate *Papilio pammon.* Captive monkeys also rejected *Danais* (p. 23).

Attempts to feed species of *Danais, Pharmacophagus, Delias,* and *Euschema* to tame chickens were unsuccessful (p. 99).

Danais septentrionalis was rejected by caged lizards (*Calotes mystaceus*) (p. 99).

The following, appended in bibliographic form, are self-explanatory:

DONISTHORPE, H. ST. J. K. Cases of Protective Resemblance, Mimicry, etc., in the British Coleoptera. *Trans. Ent. Soc. Lond.*, 1901.

Three species of lizards were found to reject the Telephorid, *Psilothrix nobilis* (p. 362).

Specimens of *Melasoma populi* "were pecked at, but finally refused, though killed, by Shama, Pied Mynah, Laughing Jackass and Brambling. The Drongo and *Graculipica nigrirostris* ate several." The author says: "It appears to me that their refusal by so many insect-eaters *in confinement* conclusively proves their distastefulness" (p. 368). It proves nothing of the sort. Moreover, "distastefulness" of the kind here claimed seems to be no protection at all. Specimens of *Cassida equestris* were eaten by all the birds to which they were offered (p. 369).

SHELFORD, R. Observations on some Mimetic Insects and Spiders from Borneo. *Proc. Zool. Soc. Lond.*, 1902, pp. 230–284, pls. 19–23.

Two tame monkeys (*Macacus cynomolgus*) manifested disgust after tasting specimens of the Reduviid (*Eulyes amœna*), but ate its mimic, the mantis (*Hymenopus bicornis*) (p. 232). The writer says he has proved the distastefulness of Lycidæ, by repeated trials with various small mammals and birds (p. 244). "All the Lycidæ are strongly distasteful . . . . A strong vitality is correlated with this distastefulness: I have seen a Lycid beetle walk away apparently uninjured after it had been well pecked by two or three fowls" (p. 267).

TITCHENER, E. B., and F. FINN. Comparative Palatability of Insects, etc. *Nature*, Vol. 42, No. 1,093, October 9, 1890, pp. 571, 572.

[62] Haase, E., *Researches on Mimicry*, Part II, Stuttgart, 1896.

The animals used in these experiments were domestic mice, toads, a mynah (*Acridotheres tristis*), a heron (*Ardea cinerea*), a prairie owl, a water tortoise and a lizard. The results of the experiments are described in detail, but no general conclusion is given. At least seven of the things offered as food were both accepted and refused by the same species of animal. This number included the common earthworm (*Lumbricus terrestris*).

TITCHENER, E. B. Comparative Palatability. *Nature*, Vol. 44, No. 23, October 8, 1891, p. 540.

Experiments with frogs, toads and ducks, supplementary to the above; no general remarks.

TITCHENER, E. B. Comparative Palatability. *Nature*, Vol. 45, No. 3, November 19, 1891, p. 53.

These experiments relate to the choice of food by captive goldfish, silverfish, frogs, and a spider. The details are given without comment.

BIRDS.

Experiments in Europe.

Birds have been used more frequently than animals of any other class to test the potency of the protective adaptations of insects and other groups under experimental conditions. One of the most important series of experiments was carried on chiefly as a study of the origin of the process by which food is accepted or rejected by birds. In this series Prof. C. Lloyd Morgan performed various experiments with young chicks, pheasants, guinea-fowls, moorhens, and ducks, the net result of which "is that, in the absence of parental guidance, the young birds have to learn for themselves what is good to eat and what is distasteful, and have no instinctive aversions."[63] The results of these experiments are often quoted by the selectionists, and as usual in such cases with sweeping inclusions not at all intended by the author. He says: "I am not, of course, prepared to say that in no case is there such instinctive aversion. . . . . Birds like the megapodes, which are hatched out in mounds apart from parental influence . . . . may show instinctive avoidances which our well-cared-for birds do not possess. That the parent bird does in most cases afford guidance is unquestionable" (pp. 43–44).

Some of the principal results that have a bearing on the value of warning colors under experimental conditions are as follows:

1. Chicks tested and rejected cinnabar caterpillars (*Euchelia jacobæ*), but ate brown loopers and larvæ of the green cabbage-moth (p. 42). A jay ate five cinnabar larvæ, but would take no more (p. 43).

[63] *Habit and Instinct*, 1896, p. 43.

2. Young moorhens found the conspicuously colored burnet moths (*Zygœna filipendula*) distasteful, the obnoxious part being the wings, for the body from which the wings were removed was eaten with apparent relish while the severed wings were rejected (p. 42).
3. *Lumbricus fœtidus* was refused at first, as were all other earthworms for some time afterwards. Later all were eaten.
4. All birds tested avoided woolly-bear caterpillars (*Arctia caja*).
5. Jays, ducks, and moorhens ate caterpillars of the tiger moths, *Nemeophila plantaginus* and *Chelonia villica*, while chicks, pheasants, and guinea-fowls found them distasteful (p. 43).
6. Jays ate pupæ of *Abraxas grossulariata* (p. 43), an insect refused by most of the captive animals to which it has been offered.
7. One jay ate a larva of *Phalera bucephala*, which another jay and duckling and chicks refused (p. 43).
8. Soldier-beetles and ladybirds were avoided (p. 43).

In No. 2, intrinsic distastefulness is not shown; it is the dry, scaly wings that are objectionable. Nos. 3, 5, and 7 give evidence for both sides of the question, and No. 6 is inconsistent with most other experiments on the same insect.

The evanescence of some associations concerning food are shown by the following experiment: Bits of orange peel were offered to a young chick that had learned to eat yolk of egg; they were refused, as were also bits of yolk substituted immediately afterward. Subsequently the yolk was again tested and accepted (p. 41).

Another test indicates that in some cases taste cannot be the criterion upon which choice is made. "While small worms are picked up with avidity, large worms are left alone by quite young birds and often evoke the alarm note. None of the chicks on the fifth day dared go near a particularly large worm. Bits of red-brown worsted, somewhat resembling worms, were seized with eagerness and eaten with surprising avidity so long as they were not more than a couple of inches long. Of a four-inch bit the chicks were afraid, until one bolder than the rest, seized it, whereupon the other chased him for the prize till he escaped to a secluded corner and swallowed it"(p. 50).

An unusual experience with customary food may lead to its rejection, as decisively as if it were "nauseous" and "warningly colored." "Pheasants and partridges, when they seized a worm for the first time, shook it and dashed it against the ground; one of them did so, indeed, with such vigor that he shook himself over, and thereafter could not for some time be induced so much as to look at a worm" (p. 51). "A little pheasant which would run to my hand for wasp

larvæ placed upon the palm, one morning gave the alarm note, and would not as usual jump upon my fingers. Four or five of the grubs had stuck together so as to form a large mass of which he was afraid!"

"Moorhen chicks were at first afraid of the common yellow underwing moth and of the gamma moth, though both were eaten freely after I had given them dead moths" (p. 50).

"Even protective coloration is of little value if there is movement, so sharp are the eyes of young birds. The caterpillar of the small white butterfly (*Pieris rapæ*) on a nasturtium leaf, with which its clear green color assimilated well, was picked off by a moorhen chick the moment it moved its head. Recently hatched stick insects (*Diapheromera femorata*), which Prof. Poulton gave me, were snapped off the lime leaves directly they moved" (p. 46).

Prof. Morgan made many tests with bees and wasps, and in summing them up says: "Much . . . . depends on the nature of initial experience. A bird that has in early days seized a bee with ill effects is shy for a long time, not only of bees, but of moths, large flies, and beetles, while one which is so stung at a later stage is made, perhaps, a little more cautious generally, but the main effect is a particularized one concerning bees or the bee-like drone fly" (p. 54).

A series of experiments, of much the same nature as Morgan's, but shorter, is described by L. W. Kline.[64] Chicks were tested with earthworms, white boring grubs, cabbage worms, and bits of yellow pine and starched muslin. "They rejected pine wood after a few experiences at the age of three days, but three days later they ate it again, while experience with muslin on the third day was lasting. They were six days getting acquainted with earthworms and eight days with canker [cabbage] worms" (p. 276).

An excellent article, previously referred to, "The Food of Some British Birds,"[65] by Robert Newstead, besides presenting the largest amount of detailed information on its subject, thus far brought forward, contains a short account of an experimental feeding of starlings. Certain food items were placed near a nest in which young were being fed. One centipede (*Geophilus longicornis*) and one earwig (*Forficula auricularia*) were refused, although each species had previously been given to the nestlings by the parent birds. Only

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[64] "Methods in Animal Psychology" [Chicks], *Amer. Journ. of Psychol.*, *10*, 1898–9, pp. 265–277.

[65] *Suppl. Journ. Bd. Agr.* [*London*], XV, No. 9, December, 1908.

one of six wood lice (*Oniscus asellus*) was accepted, and from five to seven green cherries were refused. Both of these items are eaten by adult starlings, thus rounding out to a total the contradictory evidence as to choice of the four items by the same bird under natural and under artificial conditions.

In 1889 and 1890, Mr. A. G. Butler, whose experiments with lizards are included in the tables of Poulton, previously discussed, published three articles dealing with the food preferences of captive birds. These included both British and tropical birds, which were kept in large aviaries. The first[66] of Mr. Butler's trio of papers treats only the general results of six years' experimenting. He says: "My experience . . . . has been that no insect in any stage was ever refused by all the birds; what one bird refused another would eat" (p. 171). In the course of this paper, Mr. Butler casually remarked that for two years he had sent data on the experiments to Mr. Poulton, "not even retaining a copy of my notes, but so far nothing seems to have come of it; I presume, therefore, that my facts have rather tended to mystify than clear the matter up" (p. 171). Poulton seems to have taken deep umbrage at Butler's remarks, as he returned the notes and made a hot reply on pp. 358–360 of the same volume. Butler later published his notes in full,[67] and says: "Few things ever astonished me more than the hostile attitude which Mr. Poulton assumed with regard to that innocent paper, or the cruel misconstruction which he put upon the most harmless remarks made therein; that my comment touching the repeated reproduction of a few comparatively unimportant observations of my own should have been dislocated into a claim to the origination of Wallace's theory is too absurd to be considered seriously. . . . . I still insist that, so long as a few desultory observations are incessantly forced into a front place, it is an evidence of how little has hitherto been done upon which to establish the truth of a theory; many more observers are wanted, and all their observations must be *impartially* treated if we are to arrive at exact scientific truth. I was not aware that Mr. Poulton had made a selection of 'the most interesting results' of my recent experiments for publication in the Report of the British Association, or I should not have said 'so far nothing seems to have come of it'; nevertheless, as it is impossible for any

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[66] "A few remarks respecting Insects supposed to be distasteful to Birds," *Annals and Mag. of Nat. Hist.*, Sixth Ser., Vol. IV, 1889, pp. 171–173.

[67] "Notes made during the summer of 1887 on the effect of offering various Insects, Larvæ, and Pupæ to Birds," *l.c.*, pp. 463–473.

one man to judge how far even apparently uninteresting results may eventually tell for or against a theory—as, too, Mr. Poulton has evidently forgotten some of those facts . . . . I think I cannot do better than publish the whole of my observations in detail" (pp. 463, 464).

"The most interesting results" made use of by Poulton[68] are remarks upon only four species of insects eaten by birds, while Butler's notes deal with at least forty-seven species of insects and other invertebrates. Moreover, without mentioning Butler's results, Poulton discusses the results of his own tests with lizards and a marmoset of three other species of insects, which Butler had fed to birds. Poulton gratuitously observes: "If I had no more notes than those supplied by Mr. Butler, their preparation for publication would be only a work of a few hours; but these notes are a very small fraction of the whole."[69] The fact remains, however, that the *large* "fraction of the whole," with unimportant exceptions remains unpublished to-day. As a result of this series of experiments, Butler concludes that "no insect in any stage, excepting the red-tailed bumble-bee (which, by the way, I only offered to the missel-thrush), was rejected by all my birds; those insects which were refused by certain species were eagerly devoured by others. . . . . In the second place, so far from my birds learning by experience to reject with scorn that which they had proved to be unpalatable, I found that in some instances they seemed to acquire a taste for larvæ previously refused. Birds are very intelligent, but their memories are ridiculously short" (p. 473).

Butler's third paper[70] enumerates tests of 17 invertebrates offered to birds, with the following principal conclusion: "My experiments have convinced me that the tastes of birds not only differ in individuals of the same species, but that the same individuals in consecutive years vary as to their likes and dislikes."

Unfortunately, the experiments of Butler cannot be compared with those of Pocock, who also used British insects and both native and exotic birds, as Butler does not record the number of times an insect was refused or accepted, but only tells what species of birds ate it and which did not. Probably the only coincidence of the same

[68] *Rep. British A. A. S.*, 1887 (1888), pp. 762, 763.

[69] *Ann. and Mag. Nat. Hist.*, 1889, pp. 359, 360.

[70] "Notes made during the present year on the Acceptance or Rejection of Insects by Birds," *Ann. and Mag. Nat. Hist.*, Sixth Ser., Vol. VI, 1890, pp. 324–327.

species of bird tested with the same stage of the same species of insect, in the two sets of experiments, is *Leiothrix* with larvæ of *Pieris brassicæ*. The result in each case was acceptance.

A. D. Bartlett recounts an experience in rearing young water ouzels which well illustrates the fundamental difference between experimental and natural conditions. He says:[71]

"They had been tried with the usual food for most insect-eating birds, such as scraped beef and hard-boiled eggs, ant eggs, mealworms, spiders, flies, beetles, aquatic snails, shrimps, salmon spawn, and many other mixtures, but all failed, until my clerk and assistant, Mr. Arthur Thomson, who had taken as much interest in rearing these birds as myself, hit upon the idea of scalding the mealworms, and tried it. It was soon apparent that in this condition the mealworms could be digested, while in a raw or living state they (especially their hard skins) would pass through the birds in a hard and undigested condition. From this moment I had but little trouble. The birds fed greedily upon the half-boiled mealworms, and I soon found them ready to leave the nest."

Thus these birds did not thrive upon a regimen that included several elements of their natural food, but did well only when the staple food was *partially cooked*. Mr. Bartlett adds:

"In May, 1869, I obtained my first living water ouzel. Since that time I have had a great many of these birds. Some of them I reared from the nest, and I fed them upon boiled mealworms, the larvæ of the caddis fly and other insect food; but as soon as they were able to feed themselves and took to the water, they caught and fed upon very small fish, especially young minnows. I found them rather expensive pets, having to provide for a family of four, as they caught and devoured several dozen daily, and seemed to prefer live fish to all other food."

If experimental results could be taken as a guide to natural behavior, we should conclude from this testimony that water ouzels feed largely on fish. It is worthy of note, therefore, that Newstead[72] found no fish in the stomachs he examined.

In the account[73] of the experiments by Dr. G. Rörig, previously referred to, it is stated that all of the following insects:

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[71] *Wild Animals in Captivity*, 1899, pp. 308–310.

[72] *Suppl. Journ. Bd. Agr. Lond.*, XV, No. 9, December, 1908, p. 25.

[73] *Arb. Biol. Abt. f. Land. u. Forstwirtschaft. K. Gesundheitsamte*, IV, 1903, Heft 1, pp. 34–50.

Cnethocampa pinivora, eggs and larvæ;
Fidonia piniaria, larvæ;
Euproctis chrysorrhœa, larvæ;
Clisiocampa neustria, pupæ and adults;
Liparis salicis, pupæ and adults;
Pieris brassicæ, pupæ and adults;
Porthetria dispar, adults;
Nematus abietum, larvæ;
Nematus salicis, larvæ,

were taken eagerly by captive birds, such as titmice, redstarts, kinglets, nuthatches, etc. Although the list includes hairy larvæ, some with urticating hairs, and sawfly larvæ which other experimenters state that birds usually reject, Dr. Rörig does not mention any refusals. We have already quoted his notes on the acceptance of *Pieris brassicæ*, which has been classed as distasteful. Dr. Rörig's birds also ate plant-lice, *Aradus cinnamomeus*, *Cecidomyia saliciperda*, *Retinia buoliana*, *R. turionana*, *Phyllopertha horticola*, and *Scolytidæ*.

We may note here also the experiment[74] of Dr. Günther in feeding Meloidæ to chickens. He fed the fowls from 1 to 5 grams of Cantharus daily, until a total of 28, 28, 40.5 and 80.5 g. of the material was taken by four chickens respectively. One of the birds which ate 28 g. showed symptoms of poisoning; the others remained healthy. Significant amounts of cantharidin were recovered from the bodies of these birds, and even from eggs laid by them.

Another German experiment but slightly related to the theory of protective adaptations is recorded[75] by Alexander Bau. The titmice, *Parus major* and *P. communis*, accepted in confinement eggs of *Liparis monacha*, *Porthetria dispar*, *Orgyia* spp., and *Clisiocampa neustria* (p. 69).

Brief mention should be made of the following:

[DONISTHORPE, H.] [Experiments with Birds.] *Proc. Ent. Soc. Lond.*, 1901, p. xiii.

Quoted by Rev. Canon Fowler, to the effect that *Clythra quadripunctata*, *Gonioctena rufipes*, and species of *Lina* were rejected by several species of British and foreign birds in the London Zoological Gardens. All of these beetles were eaten by a racket-tailed drongo.

LONGSTAFF, G. B. Experimental evidence as to the Palatability of Butterflies. *Trans. Ent. Soc. Lond.*, 1908, pp. 629–631.

[74] *Tierärztliches Zentralbl.*, 34, Nr. 18, June 20, 1911, S. 273–276.

[75] "Nutzen und Schaden durch die Vögel; Vogelschutz." In *Naturgeschichte der Deutschen Vögel*, by C. G. Friderich, Stuttgart, 1905, pp. 60–76.

The experiments were performed in Ceylon with *Gracula* sp., and domestic fowls. "So far as these experiments teach anything, it would appear that these mainas would eat with relish *Nissanga patina, Yphthima ceylonica, Atella phalanta, Ergolis* sp., and *Lampides* sp. On the other hand, *Papilio aristolochiæ* and *Crastia asela* were distinctly distasteful. The evidence as to the other species experimented with fails to convince me one way or the other" (p. 631). In several of the experiments the birds apparently were not hungry enough to care for anything.

Experiments in Africa.

In their extensive and interesting paper on the "Bionomics of South African Insects,"[76] Marshall and Poulton record the results of experiments with kestrels (*Cerchneis rupicoloides* and *C. naumanni*) and a ground horn-bill (*Bucorax caffer*).

The experiments with the kestrels (pp. 340–345) are characterized by the average small number of trials of the various insects used. The writer desires to draw attention to only one point in the discussion of these experiments. On p. 346, Poulton says with regard to some supposedly distasteful beetles which the birds had eaten: "It is probable that most of the defensive fluid had been already discharged in the case of the Carabidæ of the genera *Piezia, Polyhirma,* and *Graphipterus,* of which the acid secretion was seen to be a very positive protection when there was opportunity for its operation on a normal scale." The "normal scale" referred to was the offering of the beetles *tail first!* Marshall found these carabids in the stomachs of certain wild birds, and in discussing this Poulton says the fact is not remarkable, as "the defensive secretions may be discharged and lost as the result of the attacks of an experienced enemy" (p. 353). This better illustrates action on a "normal scale."

The ground horn-bill experimented upon by Marshall (pp. 347–348) ate all butterflies offered it, including several of the reputed "protected" forms, with the exception of two specimens of *Limnas (Danais) chrysippus.* Poulton, therefore, remarks: "It has already been pointed out that the acceptance of insects by insectivorous animals in captivity is no proof of their normal likes or dislikes in a wild state. . . . . Hence the fact the Acræas were devoured is no evidence that they are normally eaten except in a time of unusual hunger" (p. 348). Marshall,[77] however, says: "The bird was

[76] *Trans. Ent. Soc. Lond.,* 1902, pp. 287–504.
[77] *Trans. Ent. Soc. Lond.,* 1908, p. 139.

entirely unconfined, and wandered at will searching for its food just like his wild relatives on the next hillside, with only this exception, if insects, etc., were scarce, the . . . . bird always got additional food at the house. The conditions of the experiment, therefore, render it highly improbable that the hornbill was eating insects which it would normally reject, and its whole demeanor was quite at variance with such a supposition."

It is apparent that experts may draw very different conclusions from the same experimental data, a fact among many which points to the conclusion that the results of stomach examination are the only reliable criteria regarding bird food.

Experiments in Asia.

No experiments are more widely quoted than those performed by Frank Finn while Deputy Superintendent of the Indian Museum, Calcutta. Only those of Pocock are more extensive, and they were performed under much more artificial conditions. The results of Finn's experiments on birds are published in the *Journal of the Asiatic Society of Bengal*, as follows:

No. I. Experiments with a Babbler (*Crateropus canorus*). Vol. 64, 1895 (1896), Pt. 2, pp. 344–356.

No. IV. Experiments with various Birds. Summary and conclusions. Vol. 66, 1897 (1898), Pt. II, pp. 613–668.

The birds used in these experiments were:

Pekin robin	*Leiothrix luteus.*
Common babbler	*Crateropus canorus.*
Red-whiskered bulbul	*Otocompsa emeria.*
Common bulbul	*Molpastes bengalensis.*
Yellow-vented bulbul	*Molpastes leucotis.*
White-crested bulbul	*Pycnonotus sinensis.*
Green bulbul	*Chloropsis* sp.
White-eye	*Zosterops* sp.
Sibia	*Malacias capistrata.*
Mesia	*Mesia argentauris.*
Button quail	*Turnix taigoor.*
Bhimraj	*Dissemurus paradiseus*
King-crow	*Dicrurus ater.*
Shama	*Kittacincla macroura.*
Indian starling	*Sturnus menzbieri.*
Mynah	*Acridotheres tristis.*
Black and white hornbill	*Anthracoceros* sp.

The *Zosterops*, probably because of their small size, played a very

minor part in the experiments, caged as they were with a variety of larger birds; the *Mesia* had an exceedingly brief trial, and the *Anthracoceros* was tested principally with dead and dry insects left over from experiments with other birds. Finn remarks that of two individuals of this last species, one did not care for insects at all; the other on some occasions had to be coerced into eating insects of the supposedly palatable kinds.

In commenting upon the significance of his experiments Finn puts an emphasis on order of choice between insects, which the writer does not consider justifiable. These as all other experiments are to determine what will be eaten, and the fact that insects not eaten in the presence of the experimenter, as a rule, were devoured before his next visit or the next morning, shows the futility of drawing fine distinctions as to apparent preferences.

More than 123 butterflies which were left in the cages were eaten in the absence of the experimenter or by birds not specified, and more than 77 per cent. of them belonged to the "nauseous" group. About seventy-two butterflies remained uneaten overnight, though it should be remarked that many of these were taken later the next day. Of the seventy-two, about 85 per cent. belonged to the "nauseous" group, a percentage practically no different than in the case of those eaten. It is worthy of note that the number of butterflies left uneaten is definitely stated in every case, while those eaten are often included in general terms, as "some," "several," etc. In making these calculations, "some" has been reckoned as two; undoubtedly it sometimes meant more. These expressions occur nineteen times for the "nauseous" group among the butterflies eaten in the absence of experimenter, only once for the "palatable" group, and not at all in the case of butterflies left over. Hence there is no doubt as implied above that the proportions of these groups are about the same in the butterflies eaten as in those left over.

In the following table are shown the approximate numbers of acceptances and rejections upon trial of both the "nauseous" and "palatable" groups of insects. Species of the former group used are *Acræa violæ*, *Danais chrysippus*, *D. genutia*, *D. limniace*, *Delias eucharis*, *Euplœa* sp., *Euproctis* sp., *Mylabris* sp., *Papilio aristolochiæ*, and *Terias* sp. The principal species of the "palatable" group are *Catopsilia* sp., *Junonia* sp., *Elymnias undularis*, *Papilio demoleus*, *P. polites*, *Huphina phryne*, *Hypolimnas misippus*, *Nepheronia hippia*, *Atella phalanta*, and *Neptis kamarupa*.

	Nauseous.		Palatable.	
	A.	R.	A.	R.
Crateropus canorus	111+	36	96	1
Leiothrix luteus	52	22	94	21
Dissemurus paradiseus	30+	22	54	6
Dicrurus ater	17	2	32	4
Kittacincla macroura	21	28	78	12
Sturnus menzbieri	17	16	42	7
Chloropsis sp	6	5	16	5
Malacias capistrata	0	0	5	5
Otocompsa emeria[78]	21	7	7	6
Molpastes bengalensis[79]	15	1	10	0
Molpastes leucotis	15	0	5	0
Pycnonotus sinensis	7	9	10	1
Turnix taigoor	29	1	20	3
Acridotheres tristis	2	1	2	1
	343+	150	471	72

Finn's conclusions may be discussed in order:

1. "That there is a general appetite for butterflies among insectivorous birds, even though they are rarely seen when wild to attack them" (p. 667).

This is a thing which can never be proven by experiment. As well say there is a general appetite for boiled rice, bread and milk, and domestic cockroaches which were the stock foods of the birds used in these experiments. Certainly, these things are no more foreign to the natural dietaries of many species of birds than are butterflies, and the eating of either in captivity is no proof that they are taken or even relished by wild birds. This argument is strengthened by the record of the button-quail (*Turnix taigoor*) in Finn's experiments. This essentially ground-loving bird, which is in no way equipped for capturing butterflies under natural conditions, and consequently cannot have an appetite for them, in captivity took all but four out of a total of fifty-three that it tried.

Mason and Lefroy, in the most comprehensive and valuable statement yet published regarding the food of birds in India, say:[80] "Butterflies do not form any appreciable proportion of the food of

[78] Finn records the refusal of *Acræa* by the red-whiskered bulbul (p. 640), while Poulton (*Proc. Ent. Soc. Lond.*, 1908, p. xxxi) publishes a letter from H. L. Andrewes, which states that this bird was observed to feed to its young *Acræa violæ*, supposedly one of the most distasteful of the group.

[79] An interesting case of the diversity in results of experiments, and a proof, therefore, of their misleading character, probably refers to this bird, the common bulbul of India. A. G. Butler (*Nature*, 3, No. 61, December 29, 1870, p. 165) notes that a Mr. Newton, of Bombay, said it was only by repeated persecution that a caged bulbul was induced to touch a *Danais*. The record of this bird with *Danais* in Finn's experiments is A 8 R 4.

[80] *Mem. Dept. Agr. India*, Ent. Ser., Vol. III, January, 1912, p. 338.

any one species of bird, though a good many birds take these insects at times. A long series of experiments with regard to birds taking protectively colored or distasteful insects and especially butterflies was made by Mr. Finn. . . . . They have little importance to economic ornithology, since most of the experiments were conducted with caged birds, these, therefore, being under unnatural conditions."

2. "That many, probably most species, dislike, if not intensely, at any rate in comparison with other butterflies, the "warningly colored" Danainæ, *Acræa violæ*, *Delias eucharis*, and *Papilio aristolochiæ;* of these the last being the most distasteful and the Danainæ the least so" (p. 667).

By consulting the tabulation of acceptances and rejections given above, it will be seen that only two out of fourteen species of birds considerably experimented with failed to take as many or more insects of the "nauseous" group than they refused, and that seven of these fourteen species refused as large or a larger proportion of the "palatable" butterflies as of the "nauseous" ones. Consequently the assertion in Conclusion 2, at least as regards the Danainæ, is not borne out even under experimental conditions; it should read, about half of the species of birds considerably experimented with showed in captivity a greater or less degree of preference for butterflies of the "palatable" group. The figures show that about 30 per cent. of all "nauseous" butterflies tested were refused, as were about 13 per cent. of the "palatable" ones. About 23 per cent. of the Danais (average of three species) and of the Euplœas were rejected, proportions nearly as small or smaller than in the case of at least three species of the so-called palatable group, namely, *Papilio demoleus*, 25 per cent.; *Atella phalanta*, 22 per cent.; and *Elymnias undularis*, 24 per cent.

The approximate numbers of refusals and acceptances and the percentage of refusals for the important species of both groups are given below:

"Nauseous" group.

	A.	R.	% R.
Danais chrysippus	136+	38	21.8
" *genutia*	59+	23	28
" *limniace*	38+	9	19.1
Delias eucharis	13	19	59.3
Euplœa sp.	53	16	22.8
Euproctis sp.	11	2	15.3
Mylabris sp.	1+	1	50
Papilio aristolochiæ	17	33	66
Terias sp.	11	4	26.6
Acræa violæ	3	5	62.5

"Palatable" group.

Atella phalanta	16	6	22.7
Elymnias undularis	25	8	24.2
Hypolimnas misippus	13	1	7.1
Nepheronia hippia	12	1	7.6
Papilio demoleus	69	24	25.8
" *polites*	55	12	17.9

3. That the mimics of these are at any rate relatively palatable and that the mimicry is commonly effectual under natural conditions" (p. 667).

According to the figures obtained by me, the mimics, *Hypolimnas misippus* and *Nepheronia hippia* were each rejected once in thirteen and twelve trials, respectively, an average of about 7 per cent., or much under the average for the "palatable" group as a whole, while about 18 per cent. of the *Papilio polites* and 24 per cent. of the *Elymnias undularis* were refused, fully as large a proportion as in the case of several members of the "nauseous" group.

There is no more evidence for the latter half of this conclusion than that any other features of the experiments are analogous to natural conditions.

As noted above, the experiments and conclusions of Finn are often quoted in support of the selectionist theories, and Finn himself in summing up this earlier work says: "On the whole, the theory of Wallace and Bates is supported by the facts detailed in this and former papers, so far as they deal with birds (and the one mammal used)" (pp. 667, 668).

It is of great interest, therefore, to note that the builder of these oft-sought bulwarks of the selectionists later came to the opinion that neither they, nor any other of the defenses brought forward, would save the day for the selection theories. In collaboration with Douglass Dewar, in a book entitled *The Making of Species* (1909), he says: "Many naturalists, especially Dr. Wallace and Prof. Poulton, have pushed the various theories of animal coloration to absurd lengths (p. 171). . . . . We have examined these mighty images of gold, and silver, and brass, and iron, and found that there is much clay in the feet".(p. 172) . . . . What we "know of the struggle for existence offers but poor support to the Neo-Darwinian explanation of the cases of the so-called mimicry in nature" (p. 240).

As a result of his experience with captive birds, Finn recommends that future experimenters use birds in a state of freedom, and at

least one experimenter, Lieut.-Col. Neville Manders, has done so. Manders himself says: "I am extremely doubtful as to any real value accruing from experiments on caged birds, whether nestlings or adult. No one, I imagine, believes that all butterflies taste alike; no doubt some are more tasty than others, and caged birds fed upon butterflies, even with other insect food, would no doubt learn in time to distinguish the different kinds; but this procedure to my mind begs the question, as it assumes that butterflies are an ordinary article of food in the wild state, a proposition . . . . which the evidence . . . . does not altogether support."[81] It is noteworthy that the free birds Manders did induce to take disabled butterflies were not seen by him to attack these insects under normal conditions. He frequently comments (pp. 736–739, 741) on this fact. Although the birds ate the helpless butterflies, they took no notice of the freely flying ones that abounded in the vicinity.

The wild birds experimented upon in Ceylon by Manders, with their records, are as follows: (Disregarded—D.—means simply not taken and not tried. Behavior toward dead butterflies not noted).

		Nauseous group.			Palatable group.		
		A.	R.	D.	A.	R.	D.
Robin flycatcher,	*Siphia hyperythra*......	2	0	2	6	0	1
Dusky-blue "	*Stoparola sordida*.........	7	0	0	2	0	4
Brown shrike,	*Lanius cristatus*............	4	0	7	4	0	5
Magpie robin,	*Copsychus saularis*....	10	3	4+	21+	0	6
Mynah,	*Acridotheres tristis*......	11	0	1	5	0	1
		34	3	14+	38+	0	17

Thus there were no refusals (upon trial) of any living butterflies except by the magpie robin. This bird has three rejections, two of *Euplœa core*, one of which it ate immediately afterwards. The bird's record with this butterfly was A 9 R 2. Manders says the other butterfly (*Terias hecabe*) refused by this species was too dry. The percentage of insects disregarded is practically the same for the "nauseous" and the "palatable" groups. Manders' conclusion from this and other evidence is that "the terms palatable and unpalatable are not justified at present" (*l.c.*, p. 742).

Experiments in America.

Unfortunately, the natural food habits of many of the Indian,

[81] *Proc. Zool. Soc. Lond.*, September, 1911, p. 745.

African, and British birds experimented with are not well known, for the selectionists have examined very few stomachs of wild birds. This method is more arduous and does not pile up results so handsomely as do experiments. But it is, nevertheless, in connection with the strictly correlated examination of contents of other parts of the alimentary canal, and of pellets, and fæces (together with reliable records of individuals seen or collected with food in talon or beak), the only trustworthy method of learning what birds actually eat under natural conditions. And this information only is acceptable proof of the tastes and food preferences of birds or, for that matter, of any other animals.

It is fortunate, therefore, that one series of experiments has been made the results of which can be closely checked with a satisfactory amount of exact information upon the food habits of the same species under natural conditions.

Experiments by Judd and Beal.

The experiments referred to have never been published upon as a whole, though some of the results may be found in the following publications:

BEAL, F. E. L. The Bluejay and its Food. *Yearbook U. S. Dept. Agr.*, 1896 (1897), pp. 205, 206.

Birds of California in relation to the Fruit Industry. Part I, *Bul. 30, Biol. Survey*, 1907, p. 35.

JUDD, SYLVESTER D. Four common Birds of the Farm and Garden. *Yearbook U. S. Dept. Agr.*, 1895 (1896), pp. 410, 414.

The Efficiency of some Protective Adaptations in securing Insects from Birds. *Am. Nat.*, 33, No. 390, June, 1899, pp. 461–484.

The relation of Sparrows to Agriculture. *Bul. 15, Biological Survey*, 1901, pp. 45–48.

The Bobwhite and other Quails of the United States in their economic relations. *Bul. 21, Biological Survey*, 1905, pp. 28, 29, 36, 38, 40, 41, 44–45.

Doctor Judd was at one time very enthusiastic with regard to experiments in feeding birds, and these experiments were initiated and largely carried on by him. They were watched, however, and in part performed by Prof. F. E. L. Beal, the veteran economic ornithologist, who has examined the contents of more bird stomachs than any other person in the world. Prof. Beal was mainly responsible for the discontinuance of these experiments, and I am betraying no secret in asserting that experimental ornithology was abandoned

by the United States Biological Survey because of a direct realization from these trials of the futility of experiments as indications of the food preferences and, therefore, of the economic status of species under natural conditions.

It is not the writer's purpose to give a detailed account of these experiments, but merely lists of the items accepted and rejected, with comments thereon. It will be helpful to consider separately those items which were both refused and devoured. Several discrepancies exist between the statistics here presented and the published accounts previously referred to, but the writer has made the following tabulations directly from notebooks containing daily entries regarding the experiments. He believes these should be accepted as correct, rather than statements in the printed pages that have run the gantlet of editors and proof-readers, whose efforts often have just the opposite result, so far as accuracy is concerned, from that which the exercise of their true functions is intended to insure.

To interpret the bearing of this and the following experiments on the theory of protective adaptations, it should be recalled that the common types of what is called warning coloration are the combinations of black with red, yellow, and white. Metallic colors also are usually classed as warning. Besides the insects, etc., possessing these colors, other groups, for various reasons, are said to be specially defended. Among these are ground beetles (Carabidæ), many of which have acid and nauseous secretions; the true bugs (Hemiptera), nearly all pungently flavored and malodorous; ants, and the stinging wasps and bees (Hymenoptera); the spiders and centipeds with poison fangs; and the millipeds with acid juices. All of these creatures are supposed to be especially protected from the attacks of predaceous animals or, in other words, to be distasteful.

To bring out clearly the attitude of Judd's captive birds toward these categories of "protected" animals, the writer has tabulated the results (as regards the animal food only) of each series (except the shorter ones) of experiments under the following headings: "warningly colored" species, others "specially defended," and "non-protected" species. Of course, the term "non-protected" is not in accordance with the theories of protective adaptations, as the more obscurely colored and innoxious forms thus described are also said to be protected, but chiefly in a more passive way than the other two groups, namely, by concealing coloration. "Non-protected" is therefore used to bring into greater contrast the theoretical attributes of these comparatively poorly "protected" species.

Bobwhite (*Colinus virginianus*):[82]—

Accepted:

Chætopoda.

Earthworms.

Coleoptera.

Carabidæ.

Scarites subterraneus (black).

Harpalus erythropus (black, reddish legs).

Coccinellidæ.

Adalia bipunctata (red, black, and yellow).

Epilachna borealis (yellow and black).

Scarabæidæ.

Ligyrus gibbosus (red-brown).

Chrysomelidæ.

Diabrotica 12-punctata (yellow and black), 2+.

Diabrotica vittata (yellow and black), 2+.

Leptinotarsa decemlineata (yellow and black), three birds ate fifty in five minutes.

Lepidoptera.

Pieridæ.

Pieris rapæ larvæ (green, black, and yellow), 2.

Sphingidæ.

Phlegethontius sp. larvæ (green and white), 2.

Noctuidæ.

Agrotis sp. larva.

Rejected:

Coleoptera.

Coccinellidæ.

Chilocorus bivulnerus (black and red).

Meloidæ.

Meloe angusticollis (dark blue or violet, vesicant body fluids).

Homoptera.

Aphidæ.

Hymenoptera.

Tenthredinidæ, larvæ.

Summary: Colinus virginianus.—

	Accepted.		Rejected.	
	Species.	Specimens.	Species.	Specimens.
"Warningly colored" species	7	59+	2	2
Others "specially defended"	1	1	2	2+
"Non-protected" species	4	5	0	0

[82] Partial account of these experiments in *Bul. 21, Biol. Survey*, 1905, pp. 28–29, 36, 38, 40, 41, 44–45.

Thus these bobwhites ate, among other things, three species of strongly flavored yellow and black Chrysomelidæ, or leaf beetles, and two species of equally if not more pungent Coccinellidæ or ladybirds, whose colors of yellow and black and red, black, and yellow are typically "warning." On the other hand, the birds refused one red and black ladybird. It is evident considerations as to color of prey have little weight with the quail. It is worthy of note also that although these birds refused plant lice, birds experimented upon by Mrs. Margaret M. Nice ate large numbers of these insects.

Mrs. Nice's experiments upon bobwhites[83] which have previously been reviewed[84] by the writer clearly bring out the fact that birds will eat in captivity insects which they probably never eat or in some cases never even see in their normal existence. Examples are: house-flies (*Musca domestica*) and mosquitoes; 1350 and 568 of these insects, respectively, were taken at single meals, but undoubtedly they are seldom if ever eaten by wild bobwhites. Silver fish (*Lepisma saccharina*), clothes moths (*Tinea pellionella*), and mealworms (*Tenebrio*) also were eaten by the captive quail, but wild birds probably never have a chance to get these close associates of man.

The writer does not list the results of Judd's trials of quail with various vegetable foods, but only one item was refused, namely, strawberries. These are eaten by wild bobwhites and Judd comments[85] on the fact as follows: "M. B. Waite reports that near Odenton, Md., it sometimes picks ripening strawberries. Yet birds that were kept in captivity several months refused strawberries when they were hungry."

Broadwinged Hawk (*Buteo platypterus*).—

Accepted:

Lepidoptera.

Basilona imperialis imago (yellow and purplish-brown).

Bartrachia.

Bufo sp.

Aves.

Micropodidæ.

Chætura pelagica (fuscous).

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[83] "Food of the Bobwhite." By Margaret Morse Nice, *Journ. of Economic Entomology*, Vol. 3, No. 3, June, 1910, pp. 295–313.

[84] *Journ. Economic Ent.*, Vol. 3, No. 5, October, 1910, pp. 437–438.

[85] *Bul. 21, Biol. Survey*, 1905, p. 36.

FRINGILLIDÆ.
Passer domesticus (nestlings), 3.

There is no record of a refusal by this bird. The toad is supposed to be protected by acrid secretions of glands in the skin.

RUBY-THROATED HUMMINGBIRD (*Archilochus colubris*):—

Rejected:

Small Aphidæ.
" Jassidæ.
" Culicidæ.
" Other Diptera.
" Halticinæ.
" Araneida.

The leaf hoppers (Jassidæ), small flies (Diptera), flea-beetles (Halticinæ), and spiders (Araneida), at least, are common articles in the natural diet of this species.

BLUEJAY (*Cyanocitta cristata*):[86]—

Accepted:

CHÆTOPODA.
Earthworms, 7.
ISOPODA.
Oniscus asellus, 6.
CHILOPODA.
Lithobius sp., 2.
Julus sp., 2.
EPHEMERIDA.
Adults, many.
ORTHOPTERA.
ACRIDIIDÆ.
Dissosteira carolina, 1.
COLEOPTERA.
CARABIDÆ.
Agonoderus pallipes (pale yellow and black), 1.
Anisodactylus discoideus (black and brownish-yellow), 2.
" *rusticus* (brownish-black), 2.
Calosoma scrutator (metallic green, red, and blue), 1.
Chlœnius sp., 1.
Galerita janus (black and reddish-brown), 2.
Harpalus caliginosus (black), 1.

[86] Partial account in *Yearbook U. S. Dept. Agr.*, 1896 (1897), pp. 205, 206.

ELATERIDÆ.
Alaus oculatus (black and silvery, with eye-spots).
Elaterid, adult, 1.
Elaterid, larva, 1.

SCARABÆIDÆ.
Allorhina nitida (green and yellow), 1.

LUCANIDÆ.
Passalus cornutus (black), 2.

CERAMBYCIDÆ.
Typocerus sinuatus (black with yellow bands), 5.

CHRYSOMELIDÆ.
Diabrotica 12-punctata (yellow with black spots), 1.

TENEBRIONIDÆ.
Nyctobates pennsylvanicus (black), 1.
Tenebrio obscurus (dark reddish-brown), 1.
Tenebrionid undet., 1.

HETEROPTERA.

PENTATOMIDÆ.
Brochymena sp., 1.

LEPIDOPTERA.
Philosamia cynthia (yellow and purplish-brown), 3 (alive and dead).
Telea polyphemus ad. (mainly reddish-brown, white and black, eye spots on each pair of wings), 1.
Orgyia leucostigma, pupæ, 2.
Hyphantria cunea, larvæ (very hairy), many.
Hairy caterpillar, undet., 1.
Cutworm, 1.

HYMENOPTERA.

APINA, 2.
Agapostemon sp. (metallic green), 1.

ARANEIDA.
Spider, 1.

AVES.

PHASIANIDÆ.
Egg shells.

FRINGILLIDÆ.
English sparrow eggs, 2.

Rejected:

ORTHOPTERA.

BLATTIDÆ.
Stylopyga orientalis (black).

HETEROPTERA.

BELOSTOMATIDÆ.
Benacus griseus (light brown).

COLEOPTERA.

LAMPYRIDÆ.

Chauliognathus pennsylvanicus (yellow and black), 3.

CHRYSOMELIDÆ.

Chrysochus auratus (metallic green and coppery).

LEPIDOPTERA.

PAPILIONIDÆ.

Papilio troilus adult (dark red-brown, white, and bluish-green).

PULMONATA.

LIMACIDÆ.

Limax sp.

AVES.

PHASIANIDÆ.

Hen's egg (whole).

FRINGILLIDÆ.

Passer domesticus (alive), in cage three days.

MAMMALIA.

MURIDÆ.

Mus musculus (alive).

SPERMATOPHYTA.

MORACEÆ.

Morus sp. (berry), 2.

AQUIFOLIACEÆ.

Ilex opaca, berry (red), 2.

Disregarded:

COLEOPTERA.

COCCINELLIDÆ.

Adalia bipunctata (red, black, and yellow), 2.

Hippodamia sp., 1.

CHRYSOMELIDÆ.

Galerucella luteola (yellow and black), 3.

LEPIDOPTERA.

PAPILIONIDÆ.

Papilio turnus ad. Killed, dropped when frightened by observer, not picked up (mainly yellow and black), 1.

HYMENOPTERA.

APINA.

Apis mellifera, worker (brown), 1.

SPERMATOPHYTA.

FAGACEÆ.

Fagus grandifolia, nuts.

MYRTACEÆ.

Citrus sp., whole fruit.

Accepted and Rejected:

ORTHOPTERA.

GRYLLIDÆ.

Gryllus sp., A 1 R 1.

COLEOPTERA.

CARABIDÆ.

Scarites subterraneus (black), A 2 R 1.

HYDROPHILIDÆ.

Hydrophilus triangularis (shining greenish-black), A 2 R 2.

SCARABÆIDÆ.

Ligyrus gibbosus (reddish-brown), A 17 R 2.

HYMENOPTERA.

Bombus sp., A 1 R 1.

Xylocopa virginica, worker (black with yellow hairs), A 1 R 1, male A 1.

MAMMALIA.

MURIDÆ.

Mus musculus (dead), A 3 R 1.

Accepted and Disregarded:

COLEOPTERA.

SCARABÆIDÆ.

Lachnosterna sp. (reddish-brown), A 3 D 2.

HYMENOPTERA.

MYRMICIDÆ.

Tetramorium cæspitum (a minute reddish ant), A 1, D many.

Accepted, Rejected, and Disregarded:

ORTHOPTERA.

BLATTIDÆ.

Blattella germanica (yellow-brown and dark brown), A 16+ R 1 D 1.

COLEOPTERA.

SCARABÆIDÆ.

Dyscinetus trachypygus (black), A 5 R 2 D 2.

LEPIDOPTERA.

Philosamia cynthia, cocoons. One pecked, could not be opened, was left; two others disregarded were afterwards eaten when cut open.

SPERMATOPHYTA.

FAGACEÆ.

Quercus sp. (acorns), A 8+ D several, R.

Disregarded and Refused:

COLEOPTERA.

Leptinotarsa decemlineata (yellow and black), D 1 R 2.

LEPIDOPTERA.

Colias philodice ad. (yellow and black), D 2 R 1.

Summary: Cyanocitta cristata.—

	Accepted.		Rejected.		Disregarded.	
	Species.	Specimens.	Species.	Specimens.	Species.	Specimens.
"Warningly colored" species	12	21+	3	5	4	7
Others "specially defended"	8	12	1	1	1	1
"Non-protected" species	15	29	5	5	0	0

	Accepted and rejected.			Accepted and disregarded.		
	Species.	Specimens.		Species.	Specimens.	
"Warningly colored" species	2	A 3	R 2	0	A 0	D 0
Others "specially defended"	1	2	1	1	1	1+
"Non-protected" species	4	23	6	1	3	2

	Accepted, rejected and disregarded.				Disregarded and rejected.		
	Species.	Specimens.			Species.	Specimens.	
"Warningly colored" species	0	A 0	R 0	D 0	2	D 3	R 3
Others "specially defended"	0	0	0	0	0	0	0
"Non-protected" species	3	24+	4	5	0	0	0

Imagos of *Philosamia cynthia*, at least, among the things accepted are seldom or never encountered by wild bluejays. This species was imported with its food plant *Ailanthus glandulosus*, and is established in very few places. The cocoons of this species could not be opened by the jay, but when opened for him the pupæ were eaten. Of the items refused, hen's eggs are all too often attacked by wild birds; living birds and mice are frequently killed and eaten, and mulberries also are eaten under natural conditions.

Among things both accepted and rejected, crickets (*Gryllus*) and May-beetles (*Lachnosterna*) are commonly devoured by free birds. The carabid *Scarites* also has been found in the stomach of this species. Beechnuts were disregarded by the captive jay, and acorns were both disregarded and refused, though some were afterwards eaten. Both of these nuts are frequently eaten by wild jays. These instances in themselves are sufficient to show that acceptances and

rejections by captive birds are no guide to the natural tastes of the species.

ENGLISH SPARROW (*Passer domesticus*):—

Accepted:
COLEOPTERA.
SCARABÆIDÆ.
Ligyrus gibbosus (reddish-brown), 1.
SPERMATOPHYTA.
GRAMINÆ.
Panicum sanguinale.
Chætochloa italica.
Chætochloa viridis.
CHENOPODIACEÆ.
Chenopodium album.
AMBROSIACEÆ.
Ambrosia artemisiæfolia.

Rejected:
HETEROPTERA.
PENTATOMIDÆ.
Brochymena arborea (dark brown), 1.
SPERMATOPHYTA.
CICHORIACEÆ.
Taraxacum taraxacum (heads with akenes).

Accepted and Rejected:
SPERMATOPHYTA.
AMARANTHACEÆ.
Amaranthus sp. Refused at 9 A.M. when hungry, but eaten at 11 same morning.

The fruiting heads of dandelion which were refused are a favorite natural food; and Amaranthus seeds, which were refused but eaten two hours later, are commonly eaten by wild birds of this species.

SNOWBIRD (*Junco hyemalis*):[87]—

Accepted:
ORTHOPTERA.
Encoptolophus sordidus (brown).

Rejected:
COLEOPTERA.
COCCINELLIDÆ.
Adalia bipunctata (red, yellow, and black).
SCARABÆIDÆ.
Dyscinetus trachypygus (black).

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[87] Partial account of experiments with this and the following two species in *Bul. 15*, *Biol. Survey*, 1901, pp. 45–48.

Chrysomelidæ.
Lema trilineata (yellow and black).
Meloidæ.
Epicauta sp.
Spermatophyta.
Chenopodiaceæ.
Chenopodium sp. (seeds).

The latter seeds are a common natural food.

White-throated Sparrow (*Zonotrichia albicollis*):—

Accepted:
Heteroptera.
Pentatomidæ.
Murgantia histrionica (orange and black).

Other acceptances and rejections same as with Junco, and same remark applies.

Song Sparrow (*Melospiza melodia*):—

Accepted:
Neuroptera.
Chrysopidæ.
Chrysopa sp., 1.
Orthoptera.
Encoptolophus sordidus (brown), 1.
Coleoptera.
Carabidæ.
Amara sp., 2.
Anisodactylus terminatus (dark brown to greenish-black), 1.
Harpalus pennsylvanicus (black), 1.
Nebria pallipes (black, legs yellow), 1.
Platynus sp., 2.
Pterostichus sayi (green), 3.
Trogositidæ.
Trogosita virescens (metallic green or blue), 1.
Curculionidæ.
Sitones sp., 2.
Homoptera.
Jassidæ (nymphs and adults), 3.
Heteroptera.
Lygæidæ, 1.
Reduviidæ, 1.
Lepidoptera.
Papilionidæ.
Papilio turnus, ad. (mainly yellow and black), 1.
Moths, 2.
Araneida.
Spider, 1.

SPERMATOPHYTA.
CARYOPHYLLACEÆ.
Alsine media (seeds).

Rejected:

COLEOPTERA.
CARABIDÆ.
Various Harpini were refused, but later *Harpalus pennsylvanicus* was eaten.
COCCINELLIDÆ.
Adalia bipunctata (red, black, and yellow), 1.
Hippodamia sp., 2.
SCARABÆIDÆ.
Allorhina nitida (green and yellow).
Lachnosterna sp.
CHRYSOMELIDÆ.
Diabrotica 12-punctata (yellow and black), several.
Lema trilineata (yellow and black).
MELOIDÆ.
Epicauta sp.
LEPIDOPTERA.
ARCTIIDÆ.
Leucarctia acræa, ad. (white, yellow, and black).
HYMENOPTERA.
FORMICIDÆ.
Black ant, probably *Camponotus.*
SPERMATOPHYTA.
CHENOPODIACEÆ.
Chenopodium sp.
POLYGONACEÆ.
Polygonum sp.

Accepted and Rejected:

COLEOPTERA.
CARABIDÆ.
Agonoderus pallipes (pale yellow and black), ate 2, refused others, but next day ate 15 in three minutes.
Chlœnius sp., A 1 R 1.
SCARABÆIDÆ.
Dyscinetus trachypygus (black), A 1 R 1.
Trox sp., A 1 R 2.
SPERMATOPHYTA.
AMARANTHACEÆ.
Amaranthus sp. Refused at first, finally starved into eating it.
CICHORIACEÆ.
Taraxacum taraxacum. The opened fruiting head was accepted at the only trial, the closed involucres were at first refused; several days afterwards 3 were eaten.

Summary: Melospiza melodia.—

	Accepted.		Rejected.		Accepted and rejected.		
	Species.	Specimens.	Species.	Specimens.	Species.	Specimens.	
"Warningly colored" species....	4	6	5	6	2	A 18	R 2+
Others "specially defended"......	9	13	3+	3+	0	0	0
"Non-protected" species............	3	5	2	2	2	2	3

In rejecting the seeds of *Chenopodium* and *Polygonum* this bird refused two favorite items of the food of wild members of its species; the bird was only starved into eating *Amaranthus* seeds, another favorite natural food. Of the rejected insects, *Camponotus, Diabrotica, Hippodamia,* and *Lachnosterna* have been found in collected stomachs. The acceptances include at least one insect, *Papilio turnus,* which the bird probably never gets under natural conditions. The experimenter noted that this butterfly would have easily escaped the bird had it not been confined.

LITTLE BUTCHERBIRD (*Lanius ludovicianus*):[88]—

Accepted:
- CHILOPODA.
  - *Lithobius* sp., 1.
- ORTHOPTERA.
  - ACRIDIIDÆ.
    - *Hippiscus* sp., 2.
- COLEOPTERA.
  - SCARABÆIDÆ.
    - *Copris carolina* (black), 1.
    - *Lachnosterna* sp., 1.
    - *Ligyrus gibbosus* (dead) (reddish-brown), 1.
    - *Osmoderma* sp., 1.
    - *Trichius piger* (greenish-black, reddish-brown, white; both white and yellow hairs), 1.
  - CERAMBYCIDÆ.
    - *Monohammus* sp., 1.
  - MELOIDÆ.
    - *Meloe americana* (bluish-black, vesicating juices), 1.
- HETEROPTERA.
  - PENTATOMIDÆ.
    - *Euschistus* sp., 1.
    - *Nezara hilaris* (green), 1.

[88] Partial account in *Bul. 30, Biol. Survey,* 1907, p. 35.

BELOSTOMATIDÆ.

Belostoma americanum (light brown), 1.

LEPIDOPTERA.

Ceratomia catalpæ larva (black and yellow), 2.

Estigmene acræa, ad. (white, yellow, and black), 2.

Euvanessa antiopa, ad. (reddish-brown, light blue, and yellow), 2.

DIPTERA.

Calliphora sp., 2.

PISCES.

Goldfish, 1.

Micropterus salmoides, 1.

URODELA.

Plethodon cinereus erythronotus (brown and red).

Plethodon glutinosus (black and white), 1.

REPTILIA.

Storeria dekayi (grayish-brown and black), 1.

Heterodon platyrhinus (yellow or reddish and brown or black), 1.

Sceloporus undulatus (gray or brown and black), 1.

AVES.

FRINGILLIDÆ.

Passer domesticus, 3.

VIREONIDÆ.

Vireo olivaceus, 4.

TROGLODYTIDÆ.

Telmatodytes palustris (dead), 1.

MAMMALIA.

Mus musculus, 5.

Rejected:

COLEOPTERA.

EROTYLIDÆ.

Megalodacne heros (black and yellow), 1.

LAMPYRIDÆ.

Chauliognathus pennsylvanicus (yellow and black), 1.

CHRYSOMELIDÆ.

Diabrotica 12-punctata (yellow and black), 4.

MELOIDÆ.

Epicauta vittata (yellow and black), 1.

HETEROPTERA.

PENTATOMIDÆ.

Murgantia histrionica (yellow and black), 1.

LEPIDOPTERA.

Euvanessa antiopa larva (black, spiny), 1, pupa 1.

Hyphantria cunea larva (yellow, brown, and black, very hairy), 2.

Malacosoma americana larva (black, white, and blue, hairy), 1.

Orgyia leucostigma larva (red, black, white, and yellow, hairy tufted), 1.

SPERMATOPHYTA.

ROSACEÆ.

Fragaria sp. (fruit).

Accepted and Refused:

COLEOPTERA.

CARABIDÆ.

Calosoma scrutator (metallic blue, red, and green). The butcherbird seemed to be staggered by the effluvium of one of the first Calosomas given, but devoured it. Later one was offered it rear end first through the wall of the cage; the bird ate part of the viscera, then refused to touch it again. However, he ate two the next day. In all seven were devoured.

SILPHIDÆ.

Silpha inæqualis (black), A 1 R 1.

SCARABÆIDÆ.

Trox sp., A 1 R 1. Both the *Silpha* and the *Trox* were refused in presence of experimenter, but their remains were found in a pellet thrown up by the bird about two hours later.

HYMENOPTERA.

APINA.

Apis mellifera, worker (brown), A 1 R 1; drone, A 1.

MAMMALIA.

MURIDÆ.

Mus norvegicus, A 2 R 2.

It is difficult to believe that a bird acting on principle would refuse *Epicauta vittata* and eat *Meloe americana*. *Diabrotica* is eaten by wild individuals of the species, and *Silpha*, which was both accepted and rejected by this bird, is a common capture. Calosomas also are frequently eaten by wild butcherbirds.

Summary: Lanius ludovicianus.—

	Accepted.		Rejected.		Accepted and rejected.	
	Species.	Specimens.	Species.	Specimens.	Species.	Specimens.
"Warningly colored species"	12	16	8	12	1	A7 R1
Others "specially defended"	4	4	1	2	2	3 2
"Non-protected species"	11	21	0	0	2	3 3

MOCKINGBIRD (*Mimus polyglottos*).—

Twice chose the grasshopper (*Encoptolophus sordidus*) in prefer-

ence to the May-beetle (*Lachnosterna*), although the latter is eaten by wild mockingbirds.

CATBIRD (*Dumetella carolinensis*):[89]—

Accepted:

CHÆTOPODA.
- Earthworm.

ISOPODA.
- *Oniscus asellus*, 6.

CHILOPODA.
- *Julus* sp.

ORTHOPTERA.
- Green Acridiid.

COLEOPTERA.

CARABIDÆ.
- Undetermined, 11.
- *Agonoderus pallipes* (pale yellow and black), 1.
- *Anomoglossus pusillus* (bluish-green, blue, or black).
- *Bembidium chalceum* (coppery to greenish or black).

STAPHYLINIDÆ.
- Undet. (with red elytra), 1.

COCCINELLIDÆ.
- Undet., 1.

CUCUJIDÆ.
- *Cucujus clavipes* (larvæ), 6.

DERMESTIDÆ.
- *Dermestes talpinus* (black with variously colored hairs), 4.

SCARABÆIDÆ.
- *Lachnosterna* sp.
- *Onthophagus hecate* (black).

CHRYSOMELIDÆ.
- *Diabrotica 12-punctata* (yellow and black).

TENEBRIONIDÆ.
- *Tenebrio molitor* (reddish-brown or black), 2.

CURCULIONIDÆ.
- *Centrinus scutellum-album* (gray).

LEPIDOPTERA.
- *Euvanessa antiopa*, ad. (reddish-brown, light blue, and yellow).
- *Phlegethontius 5-maculatus*, ad. (gray, dark brown, and yellow).
- *Hyphantria cunea*, larva (yellow, brown, and black, very hairy), 5.

DIPTERA.
- *Calliphora erythrocephalus*, larvæ, 56; ad. (metallic blue, eyes dull red), 1.
- *Musca domestica* (black and gray), 2.

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[89] Partial account in *Yearbook U. S. Dept. Agr.*, 1895 (1896), p. 410.

HYMENOPTERA.
FORMICOIDEA, 7.
Lasius alienus, 22.
Cremastogaster linearis, pupa, 3.
Formica sp., 7.
Camponotus pennsylvanicus, 8.
ARANEIDA.
Lycosa sp.
PULMONATA.
Limax sp., 3.
SPERMATOPHYTA.
MORACEÆ.
Morus sp., many.

Rejected:
COLEOPTERA.
BUPRESTIDÆ.
Undet., 3 (could not break the insects).
HYMENOPTERA.
Wasp.

Disregarded:
COLEOPTERA.
Passalus cornutus (black).
LEPIDOPTERA.
Euvanessa antiopa, larva (black, spiny).

Accepted and Rejected:
COLEOPTERA.
CARABIDÆ.
Chlœnius sp., A 3 R 5.
TENEBRIONIDÆ.
Nyctobates pennsylvanicus (black), A 3 R 3.
HYMENOPTERA.
APINA.
Apis mellifera, workers (brown), A 5 R 2.
PULMONATA.
Snail (large), R 1; (small), A 2.
SPERMATOPHYTA.
ROSACEÆ.
Strawberry (*Fragaria* sp.), A several, R several.
AMYGDALACEÆ.
Cherry (*Cerasus* sp.), A 2 R several.

Accepted and Disregarded:
COLEOPTERA.
LAMPYRIDÆ.
Chauliognathus pennsylvanicus (yellow and black), D 1 A 1.

Of the insects accepted, the larvæ of *Cucujus clavipes*, at least,

which live under the bark of rotting trees, are probably never encountered by wild catbirds, but all offered the captive birds were eaten. Among the forms accepted and rejected, the nauseous metallic-green ground-beetle (*Chlœnius*) and the honey-bee (*Apis mellifera*) are eaten by wild catbirds, and both strawberries and cherries are favorite foods, as cultivators to their sorrow well know. A wasp was rejected by the captive birds, but many wasps have been found in stomachs of wild catbirds. The soldier-beetle (*Chauliognathus pennsylvanicus*), both disregarded and accepted in the experiment, is eaten under natural conditions.

Summary: Dumetella carolinensis.—

	Accepted.		Rejected.		Disregarded.	
	Species.	Specimens.	Species.	Specimens.	Species.	Specimens.
"Warningly colored" species	9	16	0	0	0	0
Others "specially defended"	10	62	1	1	1	1
"Non-protected" species	11	80	1	3	1	1

	Accepted and rejected.			Accepted and disregarded.		
	Species.	Specimens.		Species.	Specimens.	
"Warningly colored" species	1	A 3	R 5	1	A 1	D 1
Others "specially defended"	1	5	2	0	0	0
"Non-protected" species	3	5	4	0	0	0

BROWN THRASHER (*Toxostoma rufum*):[90]—

Accepted:

COLEOPTERA.

CARABIDÆ.

Harpalus caliginosus (black).

LAMPYRIDÆ.

Chauliognathus pennsylvanicus (yellow and black).

CHRYSOMELIDÆ.

Leptinotarsa decemlineata (yellow and black), twice swallowed and thrown up, then swallowed again and retained.

Diabrotica 12-punctata (yellow and black).

[90] An account of these experiments, with some additional remarks about the bird's preferences for certain human foods and wild berries, is in *Yearbook U. S. Dept. Agr.*, 1895 (1896), p. 414.

MELOIDÆ.
Epicauta sp.
HETEROPTERA.
COREIDÆ.
Anasa tristis (brown).
LEPIDOPTERA.
PIERIDÆ.
Pieris rapæ, larvæ (green, yellow, and black), 3.
ARCTIIDÆ.
Caterpillar, swallowed, but thrown up.

Rejected:
LEPIDOPTERA.
Hyphantria cunea, larvæ (yellow, brown, and black, very hairy).

Both of the insects this captive thrasher seemed to have difficulty in keeping down are eaten in the wild state. All of the other insects accepted belong to "specially protected" species.

BLUEBIRD (*Sialia sialis*):—

Accepted:
ISOPODA.
Oniscus asellus, 2.
ORTHOPTERA.
GRYLLIDÆ.
Gryllus sp., 2.
COLEOPTERA.
CARABIDÆ.
Anisodactylus discoideus (black and brownish-yellow).
HYDROPHILIDÆ.
Hydrophilus triangularis (shining greenish-black), ate parts of one broken by bluejay.

Refused:
HYMENOPTERA.
APIDÆ.
Apis mellifera worker (brown).
SPERMATOPHYTA.
AQUIFOLIACEÆ.
Ilex opaca, berries (red).

Disregarded:
COLEOPTERA.
COCCINELLIDÆ.
Adalia bipunctata (red, yellow, and black).

CHRYSOMELIDÆ.
Galerucella luteola (yellow and black), 15 disregarded three times.
HYMENOPTERA.
MYRMICIDÆ.
Tetramorium cæspitum.

Accepted and Disregarded:
COLEOPTERA.
SCARABÆIDÆ.
Lachnosterna sp., A D.
ARANEIDA.
Spider, A 3 D.

Disregarded and Refused:
COLEOPTERA.
CARABIDÆ.
Scarites subterraneus (black), D R 3.

Summary: Sialia sialis.—

	Accepted.		Rejected.		Disregarded.	
	Species.	Specimens.	Species.	Specimens.	Species.	Specimens.
"Warningly colored" species	1	1	0	0	2	16
Others "specially defended"	0	0	1	1	1	1
"Non-protected" species	3	5	0	0	0	0

	Accepted and disregarded.			Disregarded and rejected.		
	Species.	Specimens.		Species.	Specimens.	
"Warningly colored" species	0	A 0	D 0	0	D 0	R 0
Others "specially defended"	1	3	1	1	1	3
"Non-protected" species	1	1	1	0	0	0

This bluebird accepted one insect—*Hydrophilus triangularis*—which very probably is never taken by wild bluebirds. The ground beetle—*Scarites*—disregarded and thrice refused by the captive bluebird has been found in collected stomachs of the species. The same is true of the only berry offered it, that of *Ilex opaca,* which the caged bird rejected. The honey bee, which was refused, and spiders and May-beetles, which were disregarded as well as accepted, are also eaten by wild bluebirds.

General Summary: All species of birds.[91]—

	Accepted	Rejected	Disregarded	Accepted and rejected.		Accepted and disregarded.	
"Warningly colored" species	137+	30	23	A 31	R 10+	A 1	D 1
Others "specially defended"	97	16+	3	10	5	4	2+
"Non-protected" species........	152	15+	1	33	16	4	3

	Accepted, rejected, and disregarded.			Disregarded and rejected.	
"Warningly colored" species............................	A 0	R 0	D 0	D 3	R 3
Others "specially defended"............................	0	0	0	1	3
"Non-protected" species..................................	24+	4	5	0	0

Totals.—

	Accepted.	Rejected.	Disregarded.	Percentage rejected.	Percentage disregarded.
"Warningly colored" species......	169+	43+	27	17.99	11.29
Others "specially defended"........	111	24	6+	17.02	4.25
"Non-protected" species..............	213+	52+	9	18.97	3.28

It appears from this final summary that Judd's captive birds rejected practically the same proportion of the "non-protected" species offered them as of the "specially protected" group. The result, therefore, is quite different from that reached in some other series of experiments. Although it harmonizes with what we believe is the average influence of predaceous animals, as a whole, upon their prey, *i.e.*, an indiscriminate one, it is no more worthy of respect than other experimental results, for the behavior of the animals experimented with did not correspond with the natural habits of their species. This is amply shown by the cases (a few not noted) in which the birds would not eat articles of food that have been found in the stomachs of wild individuals of the same species. This is more than 38 per cent. of all the items (not specimens) offered that were either disregarded or rejected; if so large a proportion of the experimental results are manifestly untrustworthy, the only safe course is to place reliance in none of them.

[91] Includes *Buteo platypterus, Archilochus colubris, Passer domesticus, Junco hyemalis, Zonotrichia albicollis,* and *Toxostoma rufum,* for which no summaries were presented in previous pages.

Bibliography of Other Experiments in America.

An annotated bibliography will sufficiently illustrate the character of other American experiments upon the food of birds. Few of them have any special reference to the efficiency of protective adaptations. The bibliography does not include citations to papers on aviculture nor on the winter feeding of birds. These are very numerous and their only merit from our present standpoint is that they afford much proof, if proof of the obvious were needed, that birds, both free and confined, will readily accept foods with which their species has never had experience under natural conditions.

Bolles, Frank. Young Sapsuckers in Captivity. *Auk,* IX, No. 2, April, 1892, pp. 109–119.

Proof that they can live a long time on a diet of syrup with very few insects.

Carpenter, F. H. Screech Owls Breeding in Confinement. *Ornith. and Oologist,* 8, No. 12, December, 1883, pp. 93, 94.

"I fed them exclusively on frogs. . . . . They seemed to prefer them to any other food, which led me to believe that they constituted no mean portion of their regular fare when at liberty."

This inference is not supported by the results of stomach examinations. Dr. Fisher found frogs in only two out of a total of 255 stomachs examined (*Bul. 3, U. S. Biological Survey,* 1893, pp. 169–173).

Collins, C. W. Some Results from Feeding Eggs of *Porthetria dispar* to Birds. *Journ. Economic Ent.,* 3, No. 4, August, 1910, pp. 343–346.

Some English sparrows and a pigeon were tested. In all cases it was necessary to force the birds to eat the eggs. Eggs in dough fed to English sparrow were mostly rejected.

Collins, J. W., *et al.* [Food of Young Ruffed Grouse.] *Rep. Comm. Inland Fisheries and Game, Mass.,* 1900 (1901), p. 43.

Some young ruffed grouse which had been fed on maggots, lettuce, and young clover were given grain, and as a result died. Were they also given gravel?

F. G. The Pine Grosbeak in Confinement. *Ornith. and Oologist,* 9, No. 4, April, 1884, p. 41.

Fond of corn meal and milk, apple seeds, beechnuts, and buds and seeds of pine and spruce.

Forbush, E. H. [Food consumed by two young crows.] Useful Birds and Their Protection. *Mass. Bd. Agr.,* Boston [1907], pp. 45–48.

Chiefly concerns the quantity of food. Toads, frogs, and salamanders, often stated to be "distasteful," were eaten.

Forbush, E. H., and Fernald, C. H. The Gypsy Moth, *Porthetria dispar* (Linn.). *Mass. State Bd. Agr.,* 1896.

On pp. 231 and 239 it is stated that gypsy moth eggs were fed to a confined English sparrow and a crow. The former ate them voluntarily, but "did not appear to relish them"; the latter would not take them except when they were concealed within other food.

It will be noted that in Collins' experiment (see above) the English sparrow took the eggs only when they were forced upon it.

HERRICK, F. H. The Home Life of Wild Birds. New York, 1901.

Young kingfishers rejected raw meat, but throve on fish in captivity (p. 92).

HODGE, C. F. Our Common Birds. *Nature Study Leaflet*, Biol. Ser. No. 2, Worcester, Mass., 1899.

A young cedarbird took flies, poke berries, cabbage worms, "edema" larvæ, ants, fall web worms (a little sparingly), bush cranberries, and peppermint drops (p. 15). Mockingbirds accepted mealworms and spiders (p. 19).

HODGE, C. F. [Food of Young Ruffed Grouse.] *Rep. Comm. Fisheries and Game, Mass.*, 1903 (1904), pp. 182, 183.

"I tested them with a great variety of prepared foods—grated egg, bread crumbs, scraped raw meat, grated boiled meat, grits, boiled rice, millet and other small seeds, grass, clover, chickweed, partridge, and wintergreen berries, etc. They would either pay no attention to any of these things, or, if they did pick at them at all, would not do so but once." Foods accepted were sweet curds, earthworms, mosquito larvæ, plant lice, mealy bugs, thrips, mealworms and maggots.

HODGE, C. F. A Summer with the Bluebirds. *Bird Lore*, 6, No. 2, March–April, 1904.

"In my series of feeding tests I brought in a number of potato beetles and thoughtlessly dropped a large larva into an open mouth, before observing whether they would take them of their own accord. I noticed that they picked them up once apiece, wiped their bills in disgust, and declined to touch them again. Next morning one of the birds was dead under the perch" (p. 45).

HODGE, C. F. [Food of Young Ruffed Grouse.] *Rep. Comm. Fisheries and Game, Mass.*, 1904 (1905), pp. 132, 133.

Gives a long list of foods accepted; pears and peaches were scarcely more than tasted; thorn-apples, barberries, and black alder berries were not refused, but were taken in large quantities; they took quantities of all sorts of leaves except grape, snowball, artichoke, and *Rosa rugosa*.

Thorn-apples and black alder berries are commonly eaten by wild ruffed grouse. See *Biological Survey, Bul. 24*, 1905, pp. 36–38.

HODGE, C. F. [Food of Ruffed Grouse in Confinement.] *Rep. Comm. Fisheries and Game, Mass.*, 1905 (1906), pp. 65–68.

Gives names of numerous food items accepted. Berries of black alder were taken sparingly; oats and barley were eaten sparingly; peas and beans were refused.

HODGE, C. F. [Food of Young Ruffed Grouse.] *Rep. Comm. Fisheries and Game, Mass.*, 1907 (1908), p. 70.

Two died from swallowing objects too large to pass into gizzard (black cricket and large spider). This certainly was not the cause of death. A young ruffed grouse's digestive apparatus would quickly dispose of two such soft-bodied insects.

HODGE, C. F. [Report . . . . relative to the Propagation of Ruffed Grouse and Quail in Confinement.] *Rep. Comm. Fisheries and Game, Mass.*, 1908 (1909), pp. 60–69.

On pp. 60 and 61, Hodge says: "I encountered a new difficulty against which we must be on our guard in the future. Striped plant bugs were abundant on the grass, and were easily obtained by sweeping with insect nets. The young chicks [of ruffed grouse] ate them greedily, and simply went to sleep and died as if they had been chloroformed. These bugs had the strong odor of squash bugs, by feeding which to toads Conradi found that they died as though they had been poisoned with chloroform."

"Conradi found that five or six squash bugs might be sufficient to kill a toad, and Miss Morse has fed as many as eleven to a bobwhite at a single meal. Plant bugs are not so strong as squash bugs, and I have observed a toad eat over 250 of them in a day without showing ill effects. Still, while this evidence is not conclusive, ... I think that we should be more careful in future not to feed too many strong-smelling bugs to young grouse chicks."

Dr. Hodge's experience with the young grouse, and the bluebird, above noted, being killed by eating certain insects, is unsupported by other testimony, and the observations leading to his conclusions are not scientifically exact.

The reference to Conradi's experiments is incorrect. The toads when confined in small bottles were killed by the vaporized secretions of squash bugs; they were not killed by eating the bugs. The feeding of bobwhites is described on pp. 64–67. He justly remarks: "The most careful artificial feeding of a flock in confinement cannot approach in variety the food of wild birds" (p. 64). Reports of the Massachusetts Commissioners on Fisheries and Game for other years contain notes on the feeding of game birds in captivity, but not in relation to "protected" insects.

HYSLOP, J. A. The False Wireworms of the Pacific Northwest. *Bul. 95, U. S. Bur. Ent.*, Part V, 1912.

In the discussion of natural enemies (p. 84) are reports on experimental feedings of adult *Eleodes* chiefly to various gallinaceous birds. Chickens, ducks, the Reeves pheasant, and silver pheasant ate the beetles, while turkeys refused them, and golden and Lady Amherst pheasants would not notice them. The author says, "However, these birds seemed quite annoyed by our presence and might have eaten the beetles had they not been frightened."

JENKINS, W. E. [Blue Jay in Confinement.] *Ornith. and Oologist*, 9, No. 3, March, 1884, p. 36.

Principal foods are meat, beechnuts, and corn.

NASH, C. W. The Birds of Ontario in relation to Agriculture. *Ont. Dep. Agr.*, Toronto, 1901.

On p. 44 are the results, as to quantity of cutworms and earthworms, experimentally fed to a young robin.

OWEN, D. E. Notes on a Captive Hermit Thrush. *Auk*, XIV, No. 1, January, 1897, pp. 1–8.

Notes on quantity of earthworms and beef eaten. Worms from manure hill refused, those from garden eaten.

PECKHAM, E. G. [Fowls Eating *Argiope riparia*]. *Occas. Papers, Nat. Hist. Soc. Wis.*, I, 1889, p. 72.

This deep black and brilliant yellow spider seems to lack "one means of defence common among conspicuous creatures, *i.e.*, the possession of a nauseous flavor." "Some chickens, to which she was offered, ate her with relish."

REIFF, W. Some Experiments on the resistance of Gypsy Moth Eggs to the Digestive Fluids of Birds. *Psyche*, 17, No. 4, August, 1910, pp. 161–164.

Eggs concealed in other food were fed to a German canary, a chaffinch, a yellow hammer, a Japanese robin, a screech owl, and a carrier pigeon. The eggs given to the first three birds were put in pieces of bread. In each case part of them were picked out and rejected.

For a more complete review of the various experiments in feeding gypsy moth eggs to birds, see *Auk*, 28, No. 2, April, 1911, pp. 285, 286.

SCOTT, W. L. Baltimore Oriole. *Ornith. and Oologist*, 8, No. 11, November, 1883, p. 86.

"He is particularly fond of hard-boiled egg, bread, and finely chopped meat."

STICKNEY, J. H., and HOFFMANN, R. Bird World, Boston, 1898.

An unconfined yellow-throated vireo took cankerworms and many black ants (pp. 106–112).

TREADWELL, D. [The Food of Young Robins.] *Proc. Boston Soc. Nat. Hist.*, VI, 1859, pp. 396–399.

Discusses amount of earthworms and beef eaten per day.

WEED, C. M., and DEARBORN, N. [Food of a Captive Crow.] Birds in Their Relations to Man, 1903, pp. 61, 62.

On quantity of fish consumed.

WHEELOCK, I. G. Nestlings of Forest and Marsh, Chicago, 1902.

Young bluebirds were fed yolk of hard-boiled eggs, cracker crumbs, and earthworms (p. 34).

SUMMARY.

From the writer's point of view, three main conclusions regarding the experimental tests of the efficiency of protective adaptations

against natural enemies are unavoidable: (1) The experiments are very inconsistent; (2) They have been misinterpreted, and (3) They are not trustworthy guides to behavior under natural conditions.

The Experiments are very Inconsistent.—Inconsistency in the details of various series of experiments have been set forth in previous pages (see pp. 298, 300, 313, 316 and 319). Inconsistency in the results of entire series is plainly shown by the strongly contradictory conclusions different experimenters have drawn. Thus Weir, Poulton, Marshall, Pocock, and Finn, for instance, thought their experiments supported the selectionist theories concerning protective adaptations, while Butler, Manders, Punnett, Plateau, Reighard, and Pritchett, among others, drew just the opposite conclusion. Beddard's opinion was that distastefulness was not more definitely associated with conspicuous colors, than with plain ones. The characteristic inconsistency of experimental results are described by him in the following language:[92] "None of these experiments are thoroughly satisfactory; it is so difficult to interpret them, and they are often contradictory, for a bird will eat one day what it has refused before. The experiments that have been made are like most other statistics—they may be made to prove anything."

The Experiments have been Misinterpreted.—This charge weighs not so much against the experiments themselves as against their makers, but it throws doubt upon the desirability of such tests, since the personal equation is so large a factor in the interpretation of results.

Definite instances of misinterpretation have been cited in previous pages (295, 303, 305–316, 325 and 328–330). A chronic case is well illustrated by the following quotations from Prof. E. B. Poulton (*Trans. Ent. Soc. Lond.*, 1902):

"A mantis is probably less affected in this respect [food preferences] by confinement than a vertebrate animal; but the same general criticism will probably hold in both cases—that while the rejection of an insect by a not over-fed insectivorous animal in captivity is evidence of unpalatability or dislike, its acceptance is not sufficient evidence of appreciation or that it constitutes an element of the normal diet. An insect may be eaten readily in captivity which would be rejected or only eaten under the stress of hunger in the wild state" (p. 317).

[92] *Animal Coloration*, 1892, p. 166.

"It has already been pointed out that the acceptance of insects by insectivorous animals in captivity is no proof of their normal likes or dislikes in a wild state. Such acceptance only proves what their action would be when they had been, from some exceptional cause, kept without their normal food in its usual quantity and variety. Hence the fact that Acræas were devoured [by a ground hornbill] is no evidence that they are normally eaten except in a time of unusual hunger. On the other hand, the rejection of two *L. chrysippus*, after three Acræas had been readily eaten, indicate that the former butterfly is decidedly distasteful to this species of bird" (p. 348). . . . .

"*Byblia ilithyia* was . . . . distinguished [by baboons] from an *Acræa*, but this by no means proves that the resemblance is not beneficial under natural conditions (p. 388). . . . . Considering what has been already argued about insect-eating animals in confinement, the acceptances (excluding the Hesperiidæ) probably do not justify the conclusion that the Lepidoptera were palatable, or that they would be sought for in the wild state except under the stress of hunger" (p. 389).

"It has already been pointed out that the refusal or evident dislike of insect food by captive animals is trustworthy evidence of unpalatability, while acceptance is not proof of palatability" (p. 436).

It is self-evident that this oft-repeated dictum is merely special pleading for the admission of as much as possible of the evidence favorable to the theories, and the exclusion of as great a proportion as possible of the evidence that might be unfavorable. So plain is this fact that even Mr. G. A. K. Marshall, collaborator with Prof. Poulton in the paper quoted from, severely criticized the Professor's attitude. He says[93] in part:

"There is too emphatic an insistence upon the possibility of error where an insect is accepted; for it practically casts suspicion upon every such case. On the other hand, the possibility of error in the other direction is not indicated."

The Experiments are not Trustworthy Guides to Behavior under Natural Conditions.—The writer is by no means the first to question the analogy of behavior under experimental to that under natural conditions. The idea is put briefly by L. W. Kline in an article on "Methods in Animal Psychology":[94] "Nothing so shrinks and in-

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[93] *Trans. Ent. Soc. Lond.*, 1908, p. 140.
[94] *Amer. Journ. of Psychol.*, 10, 1898–9, p. 276.

hibits completely the fulness and variety of an organism's activities than prison life and fear."

In groups as low even as the Amphibia behavior in confinement is far from natural. Prof. C. O. Whitman found that *Necturus* ordinarily refused food in captivity on account of its extreme timidity. He says:[95] "The first adults which I kept in captivity in a large aquarium refused to eat pieces of raw beef or small fish, whether dead or alive. For months they went on, seeming entirely indifferent to any proffered food, not paying the least attention, so far as I noticed, to tempting morsels dropped quietly in front of them or held in suspension before them. Living earthworms and insect larvæ were presented to them, all of which were known to be palatable to the creature in its natural habitat; but nothing availed to draw attention or elicit any evidence of hunger. Quiet and wholly indifferent in outward behavior, yet the animals were actually starving or wasting away."

Many snakes will not take food in captivity, and it is therefore necessary to force food down their throats to prevent death from starvation. Captivity greatly modifies the behavior of some other reptiles also, as is well stated in the following quotation from H. H. Newman: "In order to understand an animal one must live with it, must spend long hours, quiet days, in thoughtful observation of it, as it pursues its daily round of occupations. This I have had an opportunity of doing, and I now feel that I have a really personal acquaintance with at least five species of tortoises. . . . .

"Studies of this sort should, I believe, precede experimental studies, for sometimes shyness or weariness might be mistaken for stupidity, and sullenness for sluggishness in reaction. As a rule, the more highly organized and alert species of tortoises display, when in captivity, the greatest degree of sullenness, and hence their actions in confinement very poorly represent their true character. The species, on the other hand, that are less highly organized are the species that act more nearly normally when in captivity. . . . . Captivity inhibits normal activity in nearly all tortoises; consequently I abandoned at an early stage of my work the observation of specimens in confinement and devoted myself to long-continued, and at times tedious, observation of the various species as they live in their active environment. . . . .

"Extreme sullenness characterizes the behavior of *Aspidonectes*

[95] *Biol. Lectures*, 1898 (1899), pp. 295, 296.

while in confinement. If kept in a room they hide behind furniture and remain motionless for hours and almost days. When put in aquatic enclosures they immediately bury themselves in the mud and seem to remain there for months. Nothing will induce them to eat or to take any interest in their surroundings. If caught while making their nest, they are sometimes forced to lay the eggs, but never make a nest in confinement. The eggs are simply dropped about on land or in the water, and are usually crushed when found. None of their normal characteristics are in evidence, and it would be a waste of time to attempt to draw conclusions about their disposition or intelligence from their actions in captivity."[96]

Prof. Charles W. Hargitt makes a similar but more general criticism of the experimental method of studying animal behavior, as follows: "I have made the field work emphatic whenever at all practicable. I have elsewhere[97] emphasized the crying need for larger attention to this phase of experimental work, believing that in many cases it is all but impossible to secure trustworthy results as to behavior of animals where the work has been done under such unusual, unnatural, and artificial conditions as most laboratory provisions afford.

"What right has one to assume that the actions of an animal taken rudely from its natural habitat and as rudely imprisoned in some improvised cage are in any scientific sense an expression of its normal behavior, either physical or psychical? Is it within the range of the calculus of probability that conclusions drawn from observations made upon an animal in the shallow confines of a finger-bowl, but whose habitat has been the open sea, are wholly trustworthy? It is no part of my purpose to discredit the laboratory or laboratory appliances as related to such investigations. They are indispensable. But at the same time let it be recognized that they are at best but artificial makeshifts whose values, unless checked up by constant appeal to nature, must be taken at something of a discount. This must be especially the case with higher organisms. Some of these may, of course, be readily domesticated, or made more or less at home in aquaria or vivaria; but not a few absolutely fret their lives out, are never at ease, and probably never give expression to a natural reaction under such conditions. It seems to the writer until one has been able to place his specimens under conditions

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[96] "The Habits of Certain Tortoises," *Journ. of Compar. Neurology and Psychol.*, XVI, 2, March, 1906, pp. 126, 127, and 135.

[97] "Observations on the Behavior of Tubicolous Annelids," *Journ. Exp. Zool.*, Vol. 7, 1909, p. 157.

approximating the natural, or has at least brought them to a state of semi-domestication, where in food taking, evidence of health, etc., they are at ease, he has small right to dogmatize as to conclusions, or presume to make such conclusions the basis of so-called *laws of animal behavior*. Not a little of recent investigations along the lines of animal behavior has been vitiated at just this point, and must be repeated to be made trustworthy. The amazing mass of contradictory results which has loaded the literature of recent years is attributable to some extent to this misfortune."[98]

With regard to experimentation with captive birds, Prof. S. A. Forbes, the founder of economic ornithology, says:[99] "This evidently shows only what the bird *will* eat when restrained of its liberty, of such food as may be placed before it, and furnishes few data which we can use with safety in making up an account of its food in freedom, when foraging for itself. The state of confinement is so abnormal for a bird that on this account, also, we can rarely reason from its habits in that state to its ordinary habits. This method is, therefore, available only for the solution of a few separate questions."

The assertions of these authors regarding the modifying effects of captivity upon behavior apply more pertinently to no set of experiments than those which have been conceived to be tests of the food preferences of insectivorous animals in relation to protective adaptations.

The writer has asserted that the experiments are not trustworthy guides to behavior under natural conditions, and he expects to prove this by citing evidence along two lines, viz.: (1) Animals accept in captivity articles of food which they not only do not eat in the wild state, but with which their species probably has never had experience, and (2) animals reject in captivity articles of food which are not only occasionally eaten by wild members of the species, but which may be very important elements of the subsistence as a whole.

(1) *Acceptances.*—This point really needs no proof. Universal experience with the feeding of all kinds of captive animals confirm it. The coarse brown bread (containing oats, shorts and molasses) given to the bears, in some zoological parks, the chopped-up beets, carrots, potatoes, etc., of which the parrots, cranes, and certain rodents are fond, sufficiently illustrate foods relished in confinement by animals

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[98] *Journ. of Animal Behavior*, Vol. 2, No. 1, January-February, 1912, pp. 51, 52.
[99] *Bul. Ill. State Lab. Nat. Hist.*, Vol. I, No. 3, 1880, pp. 86, 87.

to which they are unknown in the wild state. The experiments of Pocock and Butler, resulting in the acceptance of many British insects by a variety of foreign mammals and birds, illustrate the same point. As noted before, the acceptance of butterflies by some of Finn's birds signifies no more, concerning their natural food habits, than does their acceptance of boiled rice. It means no more than the eating of silver fish, clothes moths, and mealworms by Mrs. Nice's bobwhites.

The point need be no further elaborated. We are forced to conclude that acceptance of various items of food by captive animals is no indication whatever that they are eaten by the same species in the wild state.

(2) *Rejections.*—This point really follows from analogy the conclusion just cited. There is no logic in regarding rejections as indicative of natural tastes, when acceptances are plainly shown not to be. But evidence to prove the case is much harder to obtain, and it is for this reason that we have been compelled to endure the style of argument that asserts "refusal . . . . is trustworthy evidence of unpalatability, while acceptance is not proof of palatability."

Fortunately, however, we have information regarding the choice of food by a number of animals, both in captivity and under natural conditions. We have shown that in certain of the experiments with amphibia, the animals refused articles of food which they habitually eat in the natural state. For instance, this is true of the refusal by the common toad of the Eastern United States of millipeds (*Julus*), squash-bugs (*Anasa tristis*), and potato beetles (*Leptinotarsa decemlineata*). Prof. Whitman found that ordinary articles of the natural diet were refused by captive *Necturus*. Snakes, in particular, often refuse all food in confinement. Is this "trustworthy evidence of unpalatability?" The writer had the care for a year of six prairie rattlesnakes (*Sistrurus catenatus*). Live mice and birds put in their cage were killed, but not eaten. No food was taken naturally and they were kept alive only by putting meat well down their gullets with long-jawed forceps.

Beddard found that a green woodpecker made great objection to eating a single earwig, yet Newstead found twenty-three of these insects in the stomach of a wild bird of this species. Finn found that captive red-whiskered bulbuls refused *Acræa*, but an observer in India saw the birds feeding the "most distasteful" insect of the genus to their young. So little is known regarding the natural food of birds in most countries that few such comparisons can be made.

Fortunately, this is not the case in the United States, where we have data enough to prove the point.

A selection of the more conspicuous cases of refusal of favorite natural foods by the birds tested by Judd are given in the following tabulation. Other instances are cited in the summaries of the separate experiments (pp. 340, 346, 349, 350 and 351).

Rejected by captive birds.	*Eaten by wild individuals of the same species.*
A ruby-throated hummingbird rejected small leaf-hoppers, flies, flea-beetles, and spiders.	All of these items are commonly eaten by wild birds of this species.
A bluejay refused a hen's egg, living birds and mice, and mulberries. Acorns also were refused.	In a state of nature jays frequently break up outlying nests of fowls. Birds and mice are preyed upon and mulberries are eaten. Acorns have been found in dozens of stomachs of wild birds and are a very important element of the normal diet.
English sparrows rejected fruiting heads of dandelion.	Whole flocks of English sparrows pass days in rifling the ripe involucres of this plant.
A snowbird, a white-throated sparrow, and a song sparrow refused seeds of lamb's quarters.	These seeds are a common natural food of all three birds.
The song sparrow rejected, also, seeds of smartweed and beetles of the genera *Diabrotica, Hippodamia*, and *Lachnosterna*.	All are eaten by wild song sparrows, the smartweed seeds in abundance.

These facts show that the feeding reactions of various animals are strikingly modified by confinement. Some animals refuse items of food which are a favorite with wild individuals of the species, some of which may form a notable percentage of the total subsistence. Others refuse all food. The birds experimented upon by Judd together disregarded or rejected 108 articles of food. Forty-two of these items have been found in stomachs of wild birds of the same species that ignored or refused them in captivity. Investigations carried on while this paper was in preparation raised this number to 42 from 35, and it must be borne in mind that subsequent stomach examinations will increase, never diminish the total. The

experimental indications as to what food items are unattractive or distasteful to the birds, thus, are proved to be misleading in 42 cases out of 108. This makes a percentage of error of 38 (which will grow larger), enough to entirely invalidate the data. Furthermore, it is not probable that the data from any other series of experiments are any more reliable. The conclusion cannot be avoided, therefore, that the rejection of various items of food by captive animals does not prove that these items are rejected by the same species under natural conditions.

Conclusion.

It has been demonstrated that behavior of captive animals toward food is not a reliable indication of what wild individuals of the same species would do in the presence of the same food. In other words, since the feeding habits of an animal in captivity may vary widely from its known habits in the natural state, there is no avoiding the conclusion that the results obtained under experimental conditions, do not indicate the part the animal might play in natural selection.

We must conclude, therefore, since acceptances and rejections in experiments bear no close relation to food preferences under natural conditions, that the value of experiments to determine the efficiency of warning colors, and other protective adaptations of prey, is very questionable. Having no certain value in themselves, they must be checked up with definite knowledge of the natural food habits. This information is obtained by collecting animals with freshly captured prey and by examination of pellets, castings, and the contents of stomachs or other portions of the alimentary canal. There is no possibility of going back of such evidence on the choice of food, nor is there any need of so doing.

Since this evidence is sufficient in itself, and since experimental data must be supported by it to be worthy of any consideration, why perform the experiments? The same time expended in collecting trustworthy data regarding the natural food habits of animals would bring much greater returns, and the result would be truth, not imaginative inferences from abnormal behavior.